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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the third year of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide is a five-part unit providing activities and experiments which build on concepts about forces learned in ZIM-SCI units H1 and H2. The material included expands students' knowledge to cover requirements of the O-Level General Science Syllabus. Parts 1 and 2 focus on two groups of forces found in the natural environment--forces acting at a distance and forces of reaction. Students are also taught about various man-made devices that apply or overcome these natural forces in a useful way. The remaining three parts focus on measurement and calculation of the size of these forces (part 3), nature of pressure and applications of pressure to useful work (part 4), and principles that govern all simple machines (part 5). Actual O-level examination questions (with answers) as well as information on principles behind the activities and experiments are provided. (JN)

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zim-SCI

YEAR 3

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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O' LEVEL STUDY GUIDE

UNIT 1 FORCES

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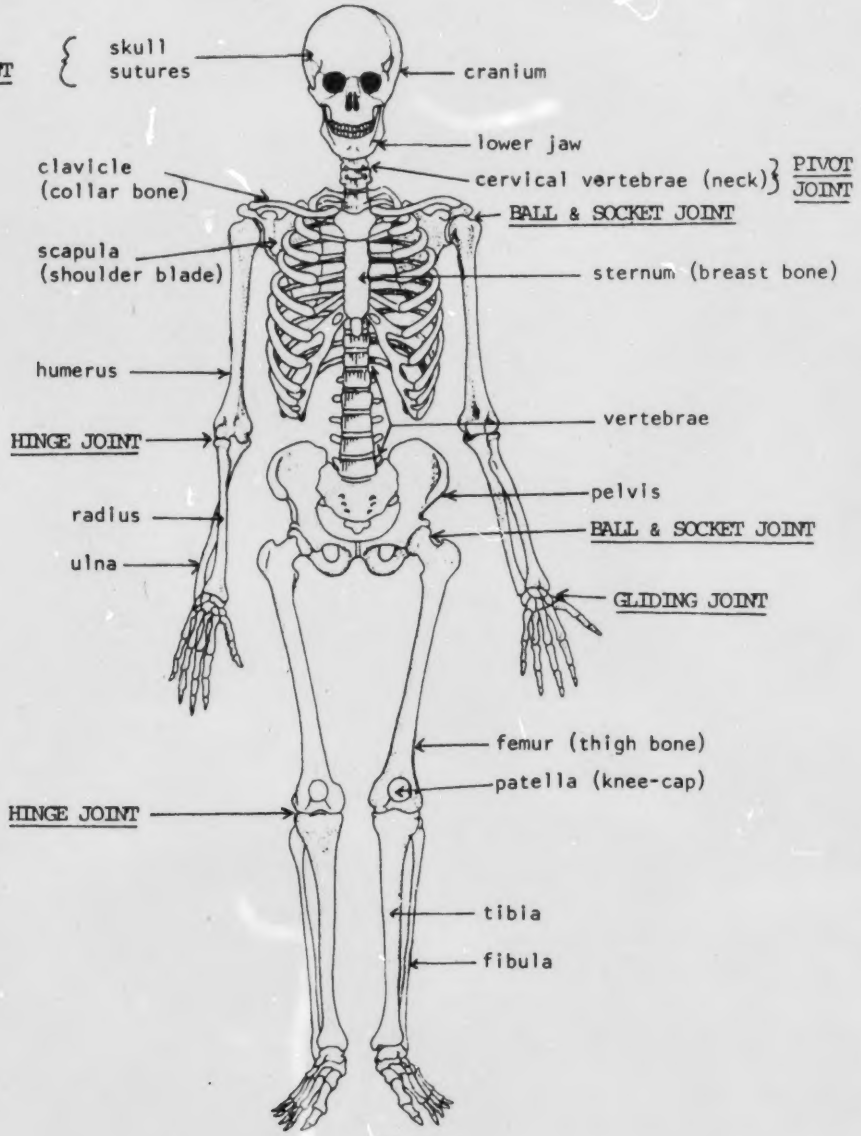
THE HUMAN SKELETON



ZIM-SCI

Zimbabwe Secondary School Science Project

GENERAL SCIENCE

STUDENTS: Please read this carefully. It will help you.

How you will study

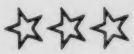
This study guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The study guide will help you to understand the scientific principles behind the experiments.

Your work should be done as you are instructed, either by the teacher or the study guide.

To help you to see quickly what you must do, the study guide uses these symbols.

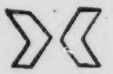
"Read and revise your notes and study guide."

E.Q. "Examination Questions" from past papers.



"Take note of an important point that you should learn."

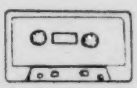
"Activity". This symbol will appear whenever you are asked to do something without your apparatus.



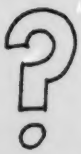
"Summary." This is to help you to go over what you have learned.

"Written work." This is when you must answer questions in writing.

"Experiment." When you see this sign, read the instructions carefully from beginning to end before you start to do the experiment.

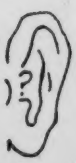


"Cassette Program". To give extra background information.



"How much do you know?" This is for you, to help you to test whether you are remembering what is important.

"Project". A chance to apply your knowledge.



Listen to the teacher and discuss the topic with him/her.

CONTENTS

	Page
Aims	1
PART 1	
Revision matter, volume & density	2
How much do you know?	5
PART 2	
More about Forces at a distance	7
Activity 1 - What is lightening?	7
Activity 2 - Gravity and thrown objects	9
Activity 3 - Weightlessness	13
Examination Questions	16
Forces of reaction	18
Experiment 1: Moving trolleys	18
Experiment 2: Jet-rocket balloon	20
Activity 4 - How high can an aircraft fly?	22
Experiment 3: Floating and sinking	24
Experiment 4: Floating a weight	25
Experiment 5: Forces of flotation	26
Activity 5 - A balloon that floats	28
Experiment 6: A drinking-straw "submarine"	30
Experiment 7: Circular motion	33
Examination Questions	35
PART 3	
Measuring Forces	38
Activity 6 - Adding vectors together	39
Experiment 8: Looking at Force Vectors	41
Experiment 9: Balancing the force of flotation	45
Experiment 10: Balancing masses	47
Experiment 11: Using a lever	51
Activity 7 - Estimating centre of mass	53
Experiment 12: Changing centre of mass	54
Experiment 13: Centre of Mass & Equilibrium	55
Examination Questions	58
PART 4	
What is Pressure	61
Experiment 14: The effect of pressure	61
Experiment 15: Atmospheric pressure	63
Experiment 16: Pressure change with depth	64
Experiment 17: Changes in water pressure with height	65
Experiment 18: Is water compressible?	66
Experiment 19: The syphon	67
Experiment 20: An Hydraulic system	68
The Blair Pump	70
The Spiral Pump	71
PART 5	
Machines & Joints	74
Cassette Programme & Project	77
Examination Questions	78

AIMS OF THIS UNIT

When you have completed this study unit, you will be able to:

1. Describe what forces are and what they can do.

2. Identify the main natural forces that can operate at a distance, such as magnetism, electricity and gravity.

3. Identify some important forces of "reaction" such as buoyancy, upthrust and flotation. Also friction and centrifugal force.

4. Explain how boats, balloons, jets, rockets and satellites use or overcome these forces in order to travel.

5. Describe how the force of friction can be usefully applied or counteracted.

6. Demonstrate how to measure forces and how to balance them.

7. Describe what pressure is.

8. Relate force, energy, work and power together.

9. Describe a number of water pumping devices utilising natural forces that are used under Zimbabwean conditions.

10. Work out : Mechanical advantage, velocity ratio and efficiency for simple machines.

11. Describe the different joints in the human skeleton and explain how they work.

'O' LEVEL UNIT 1
FORCES

PART 1

INTRODUCTION: Why are Forces Important

You will find out that whenever anything speeds up or slows down or when something changes shape it is sure indication that some force is in action. This means that everything that you do such as: using tools, using machines, or just moving your body involves you exerting a force or utilising some natural forces that already exist in the environment. This unit will give you an understanding of forces that will improve your knowledge of the world about you. Also you will understand more about how machines work and thus even be able to invent useful devices yourself.

REVISION: What is Matter?

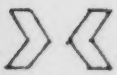
Before you can begin to learn about forces, you must check that you understand what matter is. This is because a force can only be seen in action when it causes something to happen to matter.

The Three States of Matter

You learnt about the 3 states of matter in UNIT C_2.
To remind you:
The three states of matter are: SOLID, LIQUID and GAS.
You will remember that when a sample of SOLID material is heated it can MELT to become a LIQUID. If that LIQUID is then heated up enough it can become a GAS and EVAPORATE. In both these cases the PARTICLES of Matter that make up the sample are taking in heat energy which helps them to VIBRATE more and move around more freely thus changing from state to state.

When a GAS is cooled down it CONDENSES to form a liquid and ENERGY is given out, usually as HEAT. When a LIQUID is cooled down sufficiently it will SOLIDIFY to give a SOLID, again giving off ENERGY as HEAT. This description of what the 3 states of matter are and how the particles of matter take on or give off energy when changing state is called: THE KINETIC THEORY OF MATTER.

Below is a summary of it in the form of a table.



KINETIC THEORY OF MATTER

SOLID	LIQUID	GAS
Particles are very close together.	Particles are further apart and have more energy than solid particles.	Particles are very far apart and have more energy than liquid particles.
Energy taken in →	More energy taken in →	
←	More energy given out ←	Energy given out
Particles can shake in vibrational movement but cannot move very far because they are closely packed.	Particles can travel around in the space occupied by the liquid but are not completely free.	Particles are completely free to move around a very big space.

SUMMARY

Measuring Mass

☆☆☆ The unit of mass is the KILOGRAM. We usually write this in short form as "kg". A kilogram may be divided into 1 000 divisions called grams. We write grams in a short form as "g".

Measuring Volume

Volume ALWAYS has three directions. Because of this the units have the ^{3} idea in them.

☆☆☆ Thus we have m^3 = CUBIC METRES ; cm^3 = CUBIC CENTIMETRES and mm^3 = CUBIC MILLIMETRES.

Note that the SCIENTIFIC UNIT of volume is m^3, but the others are often used because a cubic metre is a very large volume.

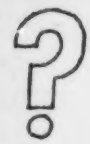
We often need to know how much space there is INSIDE something. It is very useful for measuring liquids.
Liquids are often measured using a different unit: the LITRE.
It is written in short form as l.
A litre can be divided into 1 000 parts, and these are called MILLILITRES . The short form of this is "ml".
We can match up these units with out other ones, because 1 ml = 1 cm^3.

Measuring Density

We can measure the DENSITY of all states of matter, SOLID, LIQUID or GAS. We define DENSITY as: MASS PER UNIT VOLUME.

☆☆☆ That is DENSITY = $\frac{\text{MASS}}{\text{VOLUME}} = \frac{kg}{m^3}$ or $\frac{g}{cm^3}$

Before you complete 'How much do you know?' read again the whole of this Revision section.



HOW MUCH DO YOU KNOW?

Answer the following questions in your exercise books.

1. There are three states of matter. They are called the ....., ... and ..... states.
2. When a solid is heated it becomes a .....
3. When a liquid is heated it becomes a .....
4. If a gas is cooled down it turns into a ..... and gives out ..... as it changes from one state to the other.
5. If a liquid is cooled down it .....
6. The state in which particles are very far apart is the ..... state.
7. The state in which particles are closest together is the ..... state.
8. The "scientific unit" for measuring the amount of matter in an object is the ..... For smaller objects the unit often used is the .....
9. The scientific unit for measurement of volume is the ..... but for smaller volumes the ..... or the ..... is used.
10. For measuring the volume of liquids the ..... is often used. This can be divided into 1 000 parts called ..... which are exactly the same volume as .....
11. Density is defined as ..... and its units are ..... or .....

WHAT IS FORCE?

Here is a summary of what you learnt about force in Unit H_1

SUMMARY

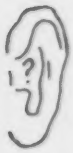
1. When a force is used energy is needed.
2. Forces, like energy, cannot be touched but can be identified by effect or action.
3. Force can speed up or slow down the movement of objects.
4. A force has a direction which is shown by an arrow (⟶).
5. Push and pull forces act in pairs in opposite directions.
6. Push and pull forces can change the shape of an object.
7. Substances which return to their original shape after stretching are said to be ELASTIC.
8. Equal forces acting in opposite directions against each other are called BALANCED forces.
9. The force with which the Earth pulls things is called the Force of Gravity.
10. Weight is a force. The weight of something is the force with which the Earth acts on that thing.
11. Forces which act at a distance are: GRAVITY, MAGNETISM and ELECTRICITY. They can make things move without touching them.

PART 2

MORE ABOUT FORCES AT A DISTANCE

In Unit H_1 you have learnt something about forces acting at a distance. Now we will look at two of these forces in more detail.

WHAT IS LIGHTNING?



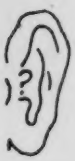
You have seen many thunderstorms and no doubt often seen lightning. When it strikes do you think that it is attracted to the ground by a force? What sort of a force could that be? Discuss this with your teacher.

Activity 1 : WHAT IS LIGHTNING ?

Take one of the balloons you have.
Rub it on a jersey or on your hair (if it's dry) to CHARGE it with ELECTRICITY.
Now hold the balloon close to, but not touching the side of your head or close to your arm.
Do you feel your hairs being gently pulled towards the balloon?
This is the electrical force.

Now think carefully, what happens when you pull your jersey off over your head (especially in dry weather)?
Do you feel a similar force attracting your hair to the jersey?
Do you hear a crackling noise?
Next time try to take your jersey off this way in a dark room.
Keep your eyes open and try to look out for sparks.
You may even feel these pricking the sensitive skin on your ears.
These sparks then are a very small example of what lightning is.

Safety from Lightning



Your teacher will now give you some practical tips on how to avoid being hit by lightning!

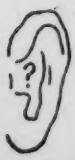
MORE ABOUT GRAVITY

The force with which the earth pulls things is called the FORCE OF GRAVITY. This force is often called WEIGHT.

Do NOT confuse WEIGHT with MASS. When someone talks about weight of a baby or a bag of mealies what they really are thinking about is how much MASS the baby or bag of mealies has. This is a common confusion which you as Zim-Scientists will not make!
Remember the MASS of a body tells you how much material is in that body. MASS is measured in kilograms. The WEIGHT of a thing is the FORCE with which the earth pulls on that thing. WEIGHT is a force and is measured in newtons .

WHAT IS GRAVITY?

Nobody knows what gravity is, but we do know what it does. Everything that has mass is affected by gravity. In fact you could say that there is a force of attraction between every single object in the universe. If this is so why then are we only attracted to the Earth? Why do we not stick to each other, the trees, the rocks, the furniture?
Discuss this with your teacher.



Activity 2 : GRAVITY AND THROWN OBJECTS

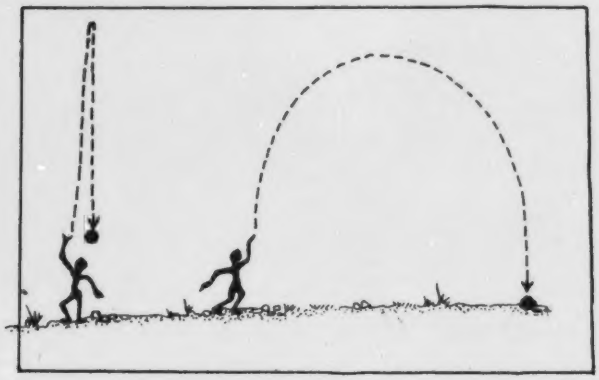
Imagine you have a ball. When you throw it high into the air what do you expect to happen?

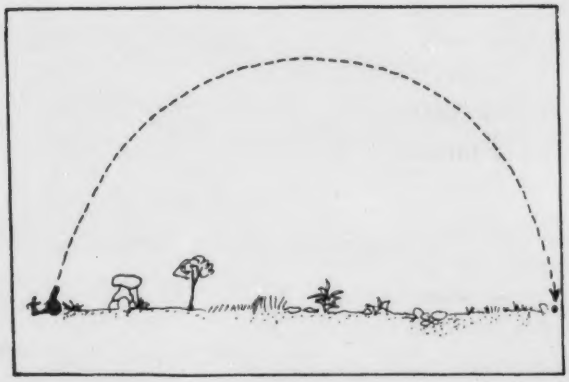
Where does the force to make it travel upwards come from?

What force is pulling the ball back to Earth?

What would happen if you could shoot the ball out of a very big gun?

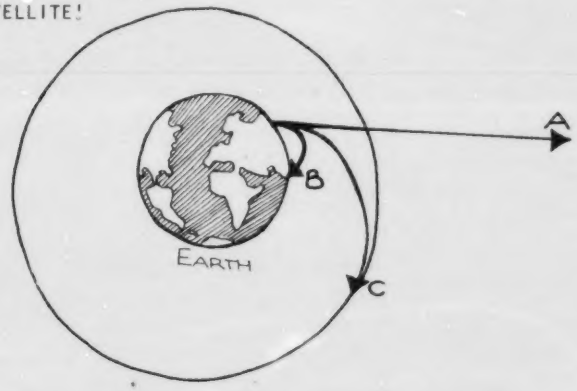
What would happen to the ball if there was no force of gravity?





Now imagine that you could throw or shoot the ball far into space but still near enough to be pulled back by the earth's gravity. If your ball went out far enough it would eventually reach a point where in falling back it would miss the Earth entirely and fall round it. If that happened your ball would then be in ORBIT around the earth.

Congratulations you have just launched the first Zimbabwean SATELLITE!



A What would happen if there was NO gravity

B What happens with a ball fired from a gun

C What happens if you shot the ball far enough to go into orbit

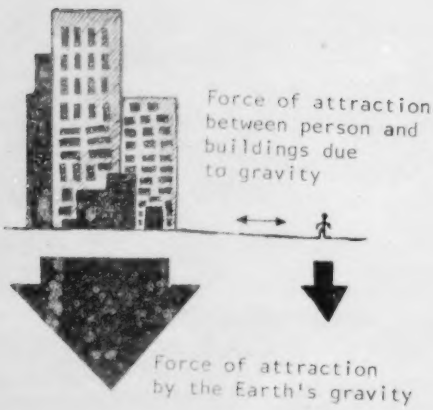
Does the Force of Gravity Change?

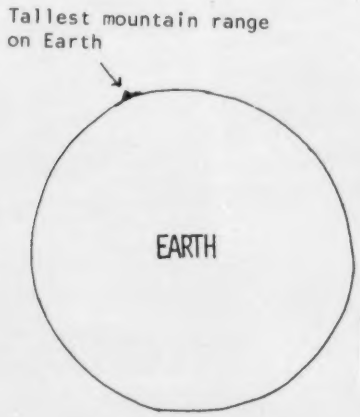
The force of gravity depends on the mass of the bodies it affects. The bigger the masses that two bodies have the greater the attraction between them. Here on Earth all objects, even the biggest mountains or buildings, have very small mass compared to the Earth itself. That is why we only feel the attraction of the Earths gravitational force and not the other objects that surround us. Actually, with very expensive and sensitive equipment it is possible to measure the gravitational forces due to mountains or large underground bodies of minerals.

In fact the size of the Force of Gravity between two objects is directly linked to how much mass the objects have. For example the moon has much less mass than the Earth so if you went up to the Moon the force of attraction (Gravity) between you and the Moon would only be $\frac{1}{6}$ of the force of gravity here on Earth.

In this case where the force between the masses gets greater or smaller as the masses get bigger or smaller we say:

☆☆☆ Force is DIRECTLY PROPORTIONAL to the masses.





The Effect of Distance on the Force of Gravity

The further away you move from the Earth, the less effect the force of Earth's gravity has on you. If you went to the Moon, for example, the Earth's gravity would be almost zero on you and you would be only really affected by the Moon's smaller gravitational force. In fact the size of the Force of Gravity between any two objects gets LESS as the distance between the objects gets GREATER.

BEST COPY

In a case such as this we say that:
Force is INVERSELY PROPORTIONAL to the Distance between the objects.

In fact, an English scientist, Sir Isaac Newton found that for gravity:

☆☆☆ Force is INVERSELY PROPORTIONAL to the Distance (between the objects) SQUARED

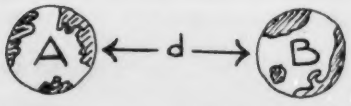
we write it as: $F \propto \frac{1}{d^2}$ ("d" stands for distance)

NOTE: $\propto$ means DIRECTLY PROPORTIONAL and $\propto \frac{1}{\text{something}}$ means INVERSELY PROPORTIONAL.

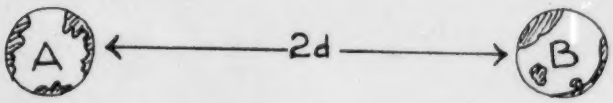
EXAMPLE

So, let us see what happens to the force when the distance is increased. Imagine that you have two planets A and B (see diagram below) that are a distance d apart. Then the force of gravity between them would be:

$$F \propto \frac{1}{d^2}$$



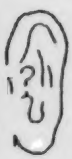
Now if we double the distance to 2d the force will become $\propto \frac{1}{(2d)^2}$



This then becomes: $\frac{1}{4d^2}$ or $\frac{1}{4}$ of $\frac{1}{d^2}$

Thus the force between A and B when they are 2d apart must be:

$$\frac{1}{4} \text{ of } F.$$



So if you double the distance the force becomes quartered.

Discuss with your teacher what would happen if you increased the distance between A and B to 3d.

Activity 3: WEIGHTLESSNESS

Imagine that you are travelling from the Earth to the Moon.
How would your weight change as you went on your journey?
Would there be a point where you would have no weight?
What does no weight (or weightlessness) mean?
Would there ever be a point at which you would have no mass?

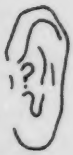
MORE ABOUT SATELLITES

When an object travels around the Earth without enough kinetic energy to escape from Earth's gravitational force but still enough energy not to fall back onto the Earth's surface we say that it is in ORBIT around the Earth. We then call such an object a SATELLITE.

Around out planet there are two kinds of satellites, ARTIFICIAL SATELLITES, which have been put up above the Earth using rockets (you will learn more about how rockets work later in this unit) and the MOON which is a natural satellite.

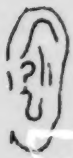
The Moon

The Moon orbits around the Earth once every 28 days and it moves very fast - about 1 km every second! However the force of attraction due to Gravity between the Moon and the Earth is strong enough to keep the Moon permanently in circular orbit around the Earth.



Discuss this with your teacher.

Use of Artificial Satellites



Your teacher will now tell you about the uses of artificial satellites and then you can discuss which of the uses would be of special interest to Zimbabwe.

SUMMARY

Forces at a Distance

1. Forces that act at a distance are: MAGNETISM, ELECTRICITY and GRAVITY.

2. MASS (measured in kg) is a measure of the amount of matter only that a body possesses.

3. WEIGHT is a measure of the FORCE with which GRAVITY pulls a mass (and is measured in N).

4. An object that travels around the Earth because its MOVING FORCE (kinetic energy) is balanced by the GRAVITATIONAL FORCE pulling it downwards is called a SATELLITE.

5. The circular path it travels is called an ORBIT.

6. The GREATER the MASSES of two objects, the GREATER the FORCE OF GRAVITY attracting them together.

7. The GREATER the DISTANCE between two objects the LESS the Force of Gravity attracting them together.

E.Q.

EXAMINATION QUESTIONS

Below are some questions.
These are taken out of past A.E.B. examination papers. Do not worry if they seem difficult. It will probably take you a little time to get used to the way the questions are put. The main thing is for you to get practice with real questions right from the beginning.

Please DO NOT write in the spaces provided under the questions. Write the answers in your exercise books instead. We have left the lines in to give you an idea of how long your answer should be.

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1.

Fig. 1 (not to scale) shows an Apollo flight path from the earth to the Moon.

Is the weight of the Lunar Landing Module least at X or Y or Z? Give the reason for your answer.

2.

Fig. 2

A small stationary object, Z, experiences weightlessness in between the two planets, X and Y, in the position shown in Fig. 2.

(*a*) What can you deduce about the masses of X and Y?

(*b*) If X and Y are of the same diameter, what can you deduce about the density of Y?

3 The force due to the Earth's gravity acting on a drifting space capsule is given by the following equation:

$$\text{Force} = \frac{\text{a constant} \times \text{mass of Earth} \times \text{mass of capsule}}{(\text{distance between Earth and capsule})^2}$$

(*a*) What will happen to the force if the distance is doubled?

.....

(*b*) Providing the mass of the capsule remains constant, what will happen to its weight when the distance doubles?

.....

4. The mass of the Moon is approximately 1/30th of the mass of the Earth, yet the force of gravity experienced on the surface of the Moon is 1/6th of the gravity experienced on the surface of the Earth. State **one** reason that might explain this observation.

.....

.....

5. Fig. 3 shows a possible system for the generation of electricity using solar energy.

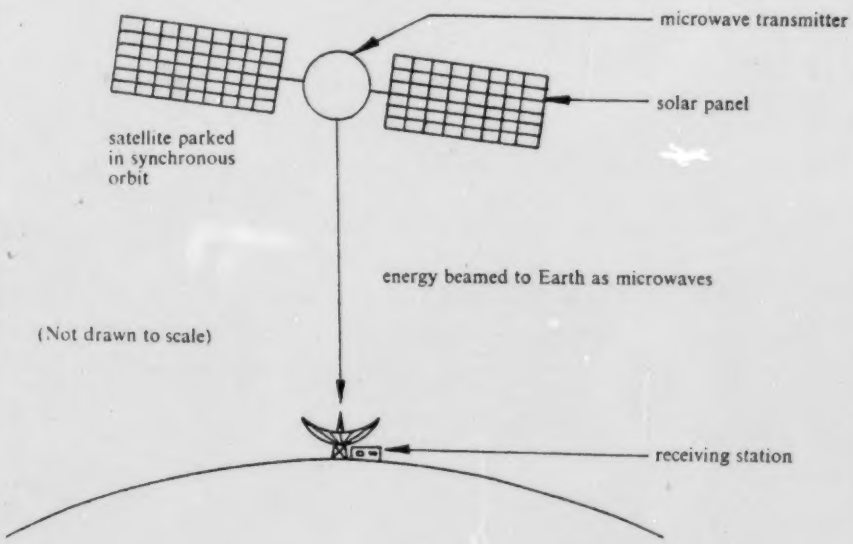

Fig. 3

(*a*) What is meant by a *synchronous orbit*?

.....

(*b*) State **one** other use of a satellite parked in a synchronous orbit.

.....

(*c*) What advantage would there be in placing the solar panel in space rather than on the Earth's surface?

.....

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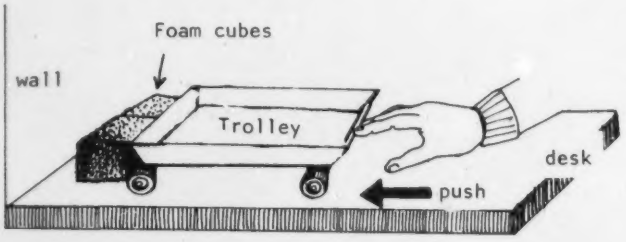
FORCES OF REACTION

So far you have looked at forces that act over a distance.
Now we will look at FORCES of REACTION.
Whenever, you apply a force to any material it will REACT to your ACTION by producing a force of its own. An obvious example: If you hit a wall, your hand will get sore because the more force you put into the wall (the harder you hit it in other words) the more force it returns to your hand!
Now you will do an experiment to discover action and reaction forces.

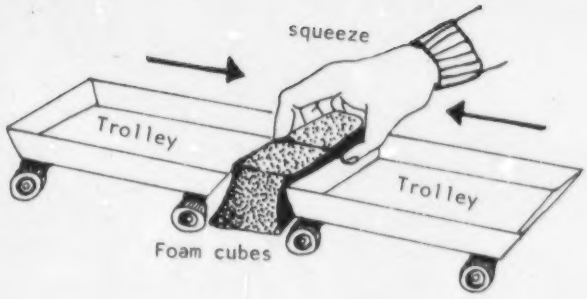
EXPERIMENT 1 : MOVING TROLLEYS

Form into groups of 4. Your teacher will give each group
2 carts (trolleys)
2 sponge cubes



a. Put the two foam cubes side by side (touching) and against the wall.
b. Push the trolley against the two cubes as far as it will go.
c. Quickly take away your hand.

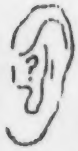
RECORD WHAT HAPPENS.



d. Now put a trolley on each side of the two foam cubes.
e. Squeeze the trolleys as close together as you can (see picture).
f. Release the trolleys and quickly take your hand away.

RECORD WHAT HAPPENS.

Now answer the questions in Exercise 1.



Now discuss with your teacher other examples you have seen where action/reaction forces have been coupled together.

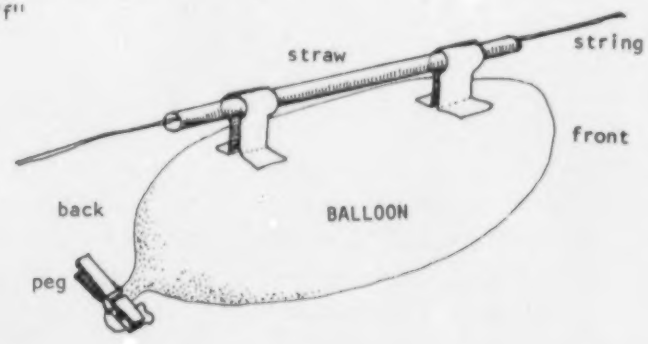
A VERY USEFUL REACTION FORCE

You will now do an interesting experiment to discover a very useful force of reaction.

Experiment 2: Jet-rocket balloon

You will need:

a piece of drinking straw (20cm)
a long balloon
2 strips of card (or stiff paper)
a length of string (about 4m)
a clothes peg (from your basic kit)
"stikistuff"



a. Blow up your balloon until it is just a bit longer than this page.
b. Your teacher will show you how to hold the end closed with a peg.
c. Stick your straw onto the balloon, using the paper strips with sticky tape or "stikistuf".
d. Then thread the string through the straw.
e. Tie the front end of the string to something solid and stretch the string tight by pulling on the back end.
f. Slide your balloon up to the back end that you are holding and take the peg off.

Record what happens!

If you enjoyed that blow up the balloon and do it again.

Now do Exercise 2.

USING THE FORCE OF ESCAPING GAS

As you know from Unit F_2 air is made up of gases and although gases are not very dense they still can exert force. You saw this force driving the balloon.
Discuss with your teacher how such a force might be made to do useful work.

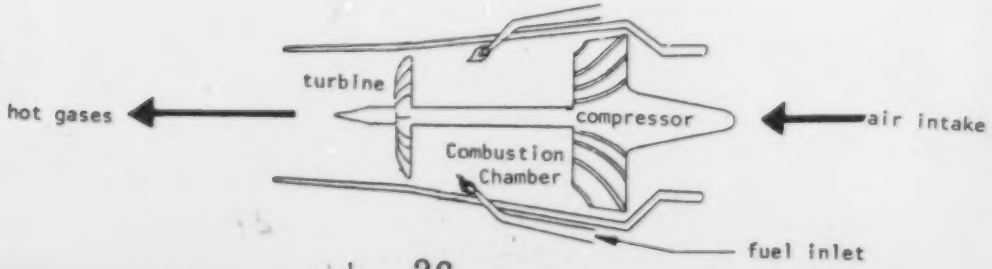
THE JET ENGINE

All aeroplanes rely on the Earth's atmosphere to be able to fly. The aircraft is driven forward because it forces the air in front of it to go backwards with propellers or jet engines.

Also their wings are made in a special shape. This causes differences between the air pressure pushing on the top and the bottom surfaces of the wing. The wing is constructed so that the pressure on the bottom surface is the greater, thus LIFT develops which helps to get the aircraft airborne.

How it works

In the jet engine air is sucked in the front end and used to burn paraffin fuel in the COMBUSTION CHAMBER (see diagram). This burning (COMBUSTION) produces hot gases which expand with great speed and rush out the rear of the jet engine. The aircraft reacts to the force of the backward rushing gases with THRUST which is the force which drives it forward. This force is very strong indeed and this means that jet engined aircraft are much more powerful than propeller driven aircraft.



Note that as the hot gases rush from the Combustion Chamber they force their way through the blades of the TURBINE (see diagram) causing it to rotate very quickly. The turbine is linked to the COMPRESSOR. The Compressor therefore also rotates quickly causing it to suck in more air, since its blades work like a fan in reverse (that is sucking instead of blowing). This air is used then for combustion again with more fuel and gives more hot gases so the aircraft continues forward.

Activity 4: How high can an aircraft fly?

The Earth's atmosphere (as you probably already know from your geography) gets thinner and thinner (less dense) the higher up you go until eventually there is no atmosphere at all and you are in what we call SPACE. Both jets and propeller aeroplanes must have air to fly.
Can you give three reasons why this is so?

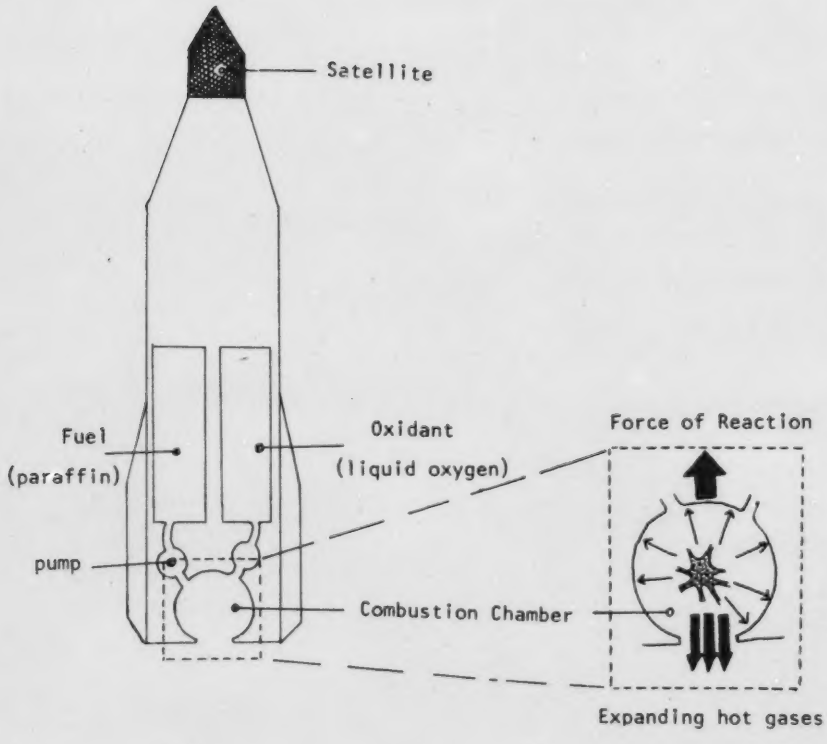
THE ROCKET

Rockets do not need air to travel in and therefore can travel through space. This is why rockets are used to launch satellites into orbit and to go to the moon.

How it works

A rocket does not need air because it carries fuel AND liquid oxygen inside it so that the fuel can be burnt in the COMBUSTION CHAMBER. The fuel (usually paraffin or liquid hydrogen) and the liquid oxygen (called the OXIDANT) are pumped from their separate tanks into the Combustion Chamber where they are ignited to produce the hot expanding gases which drive the rocket upwards in reaction to their downwards rushing force.

THE ROCKET


Satellite
Fuel
(paraffin)
Oxidant
(liquid oxygen)
pump
Combustion Chamber
Force of Reaction
Expanding hot gases

FLOTATION AND UPTHRUST AS FORCES OF REACTION

Now you will find out why you had to learn about DENSITY earlier in this unit. Very often when two substances of different densities are brought into contact with each other forces of reaction can be noticed. Forces produced in this way can often be very useful to us. You will do some experiments to discover some of these forces.

Experiment 3: FLOATING & SINKING

You will need:

a baby bath
Zim-Sci materials kit

a. Fill your baby bath with water up to near the top.
b. Take the materials from your kit (i.e. springs, metal and plastic strips and foam blocks). Hold each one, in turn, about 5cm above the surface of the water and then drop it in. If, like the springs and the strips the object has various different faces (that is some short, some long or some flat) try dropping it in two or three times, but each time drop it with a different face pointing downwards.
c. Now draw two columns in your exercise book. Head one float and the other one sink. Then record your observations on what happened to each of the materials. For those that sank all you need to put is a ✓ in the sink column. However, for those that floated make a note of how well they floated.
d. Finally, take only those that floated very well and put them each in turn on the water. Then in each case try pushing them down to the bottom of the bath and then letting go. Record what happens.
e. Now do Exercise 3.

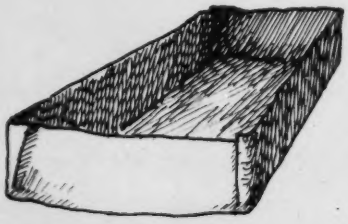
You will have noticed in the last experiment that even some of those materials that would normally sink can nearly be made to float. Let us now find out why this is so.

Experiment 4: FLOATING A WEIGHT

You will need:

A large boiling tin
A 5g mass
A 7cm square piece of aluminium foil

a. Fill the boiling tin with water up to within 1 cm of the top.
b. Take your square of aluminium foil and make it into a little "boat" as in the diagram. Make the sides of the boat about twice as high as the thickness of the 5g mass.



"Boat" of aluminium foil

5g mass

c. First drop the 5g mass into the water to see if it will sink or float.
d. Then put the 5g mass in the boat and put that on the surface of the water in the tin. Try pushing the boat down a bit but do not push it low enough to let water in.
e. Once you are satisfied that your boat floats well even with the 5g mass in it, wrap the mass very tightly in the same foil that you have just used for the boat. Do not add any extra bits or pull pieces off the foil you have used.
f. Now put this 5g mass wrapped in foil into the water in the tin. What happens? Now do Exercise 4.

So far you have seen that water reacts, to any object that pushes down on its surface, with a force pushing back up at the object. This is called FLOTATION. Those objects that are LESS DENSE than water will FLOAT. The force that pushes up is called UPTHRUST.

Do all liquids push back with the same amount of force?

Do the experiment below to find out.

Experiment 5: FORCES OF FLOTATION

You will need:

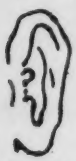
2 small plastic bottles from your basic kits
some methylated spirits
some water
the plunger from a small syringe (2½ ml)

a. Fill one bottle nearly up to the top with methylated spirits and the other with water. Make sure that they are both filled to exactly the same level (see diagrams below).

Plastic bottles

b. Carefully put your syringe plunger (black rubber end first as in the diagram) into the bottle containing the water. When it has settled make a mark on the stem with your pen. Make your mark exactly in line with lip of the bottle.

c. Then take your syringe plunger out, shake it and dry it carefully, so as not to remove your mark, with a piece of paper. Then put it into the bottle of methylated spirits. Where is the mark now?
Make a note of what you see and then do Exercise 5.

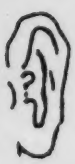


Discuss with your teacher ways in which measuring the density of liquids could be useful.

Exercise 6

Using the KINETIC THEORY you revised earlier explain why:
Cold water is more dense than hot water?
Cold air is more dense than hot air?
and salt water (sea water) is more dense than fresh water?
How would these different densities affect objects?

UPTHRUST AND GASES



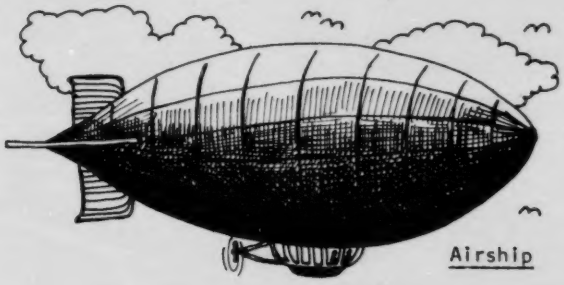
You have seen that certain solids will float on water (a liquid). Now consider what would happen if you had a gas that was lighter (less dense) than air. (Remember: Air is made up mainly of Oxygen and Nitrogen.)
Your teacher will now show you something very unusual!

Activity 5: A BALLOON THAT FLOATS ON AIR

Look at your teachers balloon. Remember earlier when you blew up balloons with air they did not behave like that one. Try to imagine what is inside the balloon and why that makes it float. Then answer the questions in Exercise 7. When you have finished and discussed your answers in class, your teacher will take you outside to see what happens if you let the balloon go.

Helium Weather Balloon

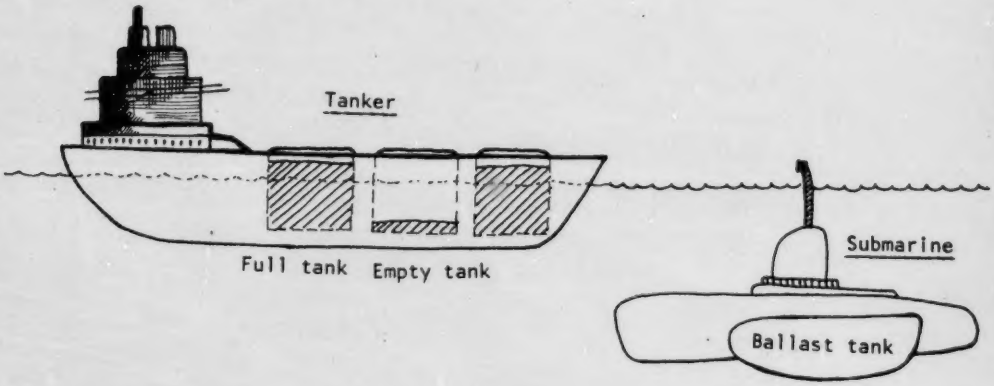
Meteorological Instruments and Transmitter



Airship

USES OF FLOTATION

There are many practical ways of using the forces of flotation. The most obvious is ships or boats which can be used to travel on or under the water, (especially the sea), carrying passengers or goods. Then there are simple instruments which measure the density of liquids, which is a useful easy way of checking a liquids purity. Finally there are balloons that can be used to carry instruments into the sky to predict weather changes or even passengers travelling great distances.



In the diagrams above you can see two interesting applications of upthrust. The Tanker has built into it empty tanks which can be filled with oil. When these are full the Tanker lies very low in the water because it has greater mass and therefore "pushes" more water aside. When its tanks are empty however it will ride higher on the water's surface, held up by the upthrust reaction force of the water.

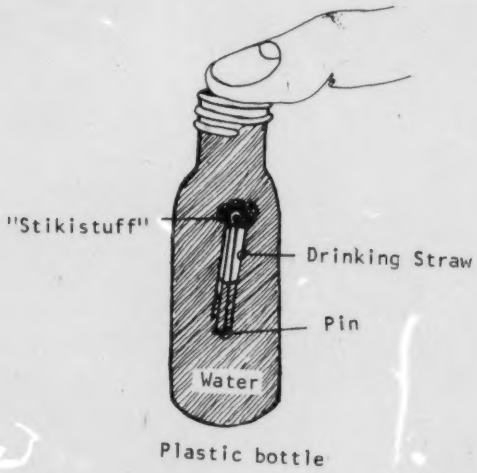
The Submarine can vary tremendously the amount of its own mass and therefore the way in which it floats or sinks. It achieves this by pumping water into or out of its BALLAST TANKS. When its ballast tanks have only air in them the submarine's reduced mass experiences enough upthrust reaction from the water to allow it to float on the surface. Then by filling its ballast tanks with water it can increase its mass sufficiently to enable it to overcome the upthrust reaction of the water to its downward pushing weight so that it then sinks. By varying the amounts of water and air in the ballast tanks the submarine can control the depth to which it will sink.

Experiment 6: A DRINKING STRAW SUBMARINE

You will need:

3 pins
some " stikistuff"
2½ cm of drinking straw
your small plastic bottle from your basic kit

a. Block one end of your piece of drinking straw with a small blob of "stikistuff".
b. Then stick 2 pins into the "stikistuff" so that they are inside your straw. (See diagram) This is now called your straw submarine.



c. Fill your plastic bottle right to the top (there must be no air in it).
d. Drop your straw "submarine" into the bottle as in diagram.

Note: Your drinking straw submarine should just float. It must not float too high out of the water and it must not sink to the bottom. You can adjust its weight by taking off or putting on "stikistuff" or by taking out pins or putting in extra pins.

e. Once your straw submarine is floating properly, cover the opening of the plastic bottle with your thumb and put the bottle on your desk.

f. Then press hard with your thumb and you submarine should sink to the bottom.

g. If you release the pressure with your thumb your submarine will rise again.

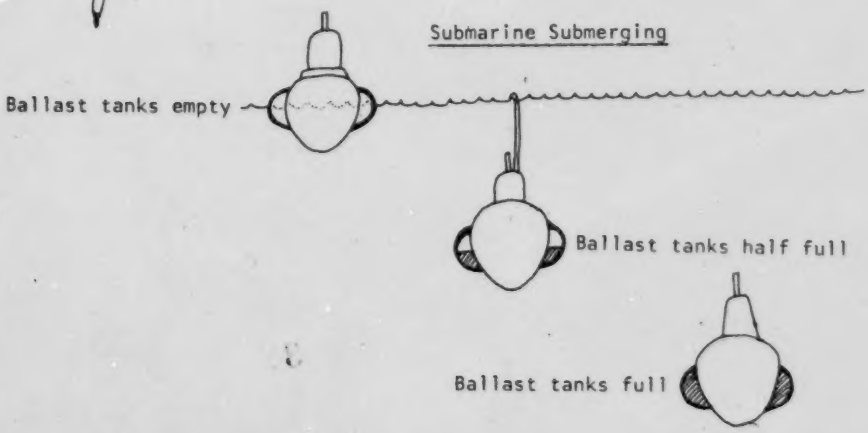
h. Try to get the submarine to stay half way down only.

How is Your Submarine Similar to a Real Submarine?

Just as a real submarine takes on water as ballast to sink below the surface, so too does your submarine. When you press your thumb down watch the water level inside the straw. The level will rise. Then because the submarine is now "heavier" it (the submarine) sinks. When you release the pressure of your thumb the air inside the submarine expands and because it is now lighter it rises.

You are changing the water level in the submarine using the force of your thumb. In a real submarine the ballast tanks are filled and emptied of water, according to whether the submarine wants to go down or up, with special pumps operated from inside the submarine.

Now do Exercise 8.



FRICTION & RESISTANCE TO MOTION

In Unit H_1 you saw that friction is a force that reacts to motion by resisting it. You have seen that it is a nuisance when you want something to move but that friction is very useful when you want something to stop.

Something else happens due to friction when you rub two surfaces together. Do you know what it is? Try rubbing your hands together, as you do if it is very cold.
HEAT ENERGY can be produced by friction.

Exercise 9.

What happens when things travel through the air?
Are they affected by frictional forces?
Think about the following problems and discuss with your teacher how friction is involved.

1. Jet aircraft use less fuel when travelling at high altitudes rather than close to the ground.
   Why is this so?

2. Satellites that fall out of their orbits and fall to Earth, usually burn up in the atmosphere before they ever reach the ground, why is this so?

FORCE FROM CIRCULAR MOTION

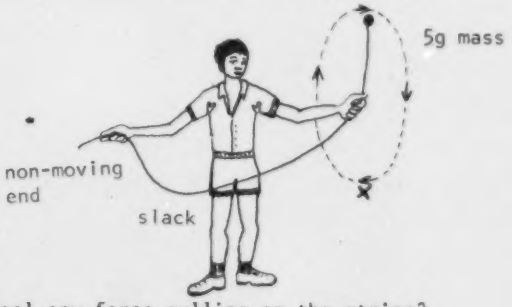
When anything moves around in a circle another Force of Reaction appears.

Experiment 7 : CIRCULAR MOTION

You will need:

a length of string about 2m long
a 5g mass

a. Your teacher will take you outside because you will need room for this experiment.
b. Tie your 5g mass onto the end of the string very well. You do not want it to fly off and hit someone in the eye!
c. Now let out about $1\frac{1}{4}$ metres of string and start whirling the mass round in a circle (see diagram).



d. Do you feel any force pulling on the string? Make a note of the direction of its pull.
e. Now hold the non-moving end of the string tightly but let go quickly with the hand that is doing the whirling. Which way did your 5g mass fly?
(Do not let the string go completely so that the weight plus string flies off to hit one of your class mates.)
f. Start again. Set up an even speed of whirling the disc round and round. Then with your other hand take up the slack and draw the string in fairly slowly so that you can see the circle, that the mass goes round in, getting smaller.

Make a note of what you saw happen.

g. Now do Exercise 10.

SUMMARY: FORCES OF REACTION

1. Whenever a force is applied to any object, it will REACT to this action producing a Force of its own, EQUAL in size but OPPOSITE in direction in an attempt to balance the original applied force.
2. Hot gas, although not very dense, can still exert a strong force of reaction. This force is used in Jets and Rockets as THRUST to move them.
3. A Jet engine must have air to operate (as this allows the fuel to burn) and thus can only fly within the Earth's atmosphere.
4. A rocket can fly in SPACE where there is no air using its own hot gases to push it because it carries its own oxygen and fuel.
5. A solid object can FLOAT in a liquid if it is LESS DENSE than the liquid.
6. The force of reaction that LIQUID pushes up with in response to a force (weight) put on its surface is called UPTHRUST.
7. An object that is more dense than a liquid can be made to float if its weight is distributed over a large surface area causing a large mass of water to be displaced and thus creating an upthrust.
8. Liquids of different densities give different amounts of upthrust to objects floating on them. Thus, for example an object will float "lower" in methylated spirits than in water and "higher" in salt water than in plain water.
9. Objects, such as balloons, containing gases that are less dense than air, such as hydrogen, will float in air, travelling upwards through the atmosphere in response to the UPTHRUST.
10. FRICTION is a FORCE that resists motion (movement). The force of FRICTION is least between smooth surfaces and greatest between rough surfaces.
11. FRICTION between surfaces can be DECREASED by the use of OIL.
12. FRICTION can be employed as a useful force in the BRAKES and TYRES.
13. FRICTION generates energy in the form of HEAT when two surfaces rub together.
14. An object can only move in a circle if there is a force pulling it inwards.

E.Q.

EXAMINATION QUESTIONS

Please DO NOT write in the spaces provided under the EXAMINATION QUESTIONS. Write the answers in your exercise books instead. We have left the lines in to give you an idea of how long your answer should be.

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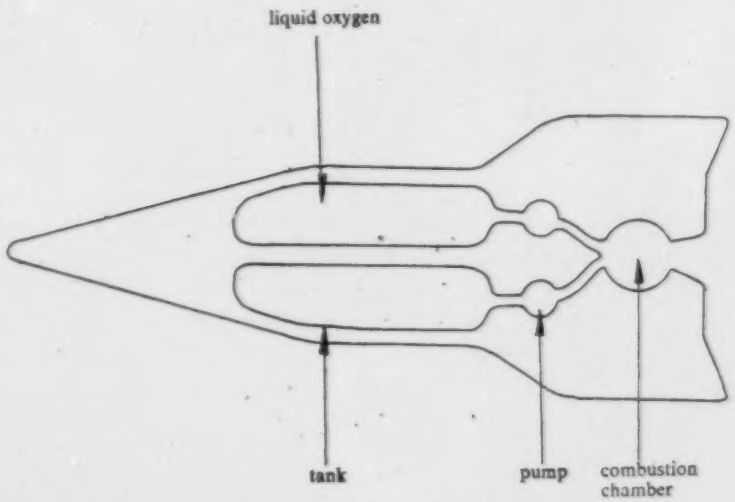

Fig. 1

Fig. 1 shows a simple rocket.

(*a*) What is the purpose of the liquid oxygen?

(*b*) Name one substance that could be found in the other tank.

(*c*) What do the rocket gases push against when the rocket is in space?

(*d*) Why should the rocket have a pointed nose?

(*e*) Why do rockets " burn-up " re-entering the atmosphere?

2. Fig. 2 shows a section through a submarine.

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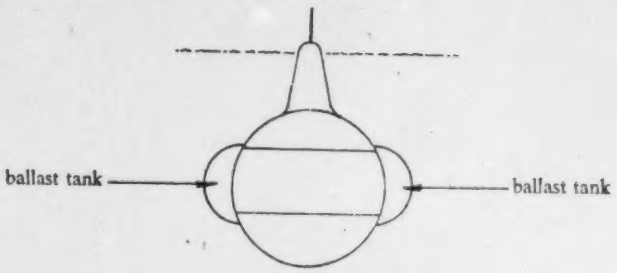

Fig. 2

(a) In order to submerge, the ballast tanks are partially filled with water. Will the mass of water admitted to the tanks be greater in warm latitudes or cold latitudes? Give the reason for your answer.

.....

.....

(b) When the submarine is just submerged, i.e. in neutral buoyancy, what can be concluded about the upthrust on it?

.....

3. (a) An oil tanker has a total mass of 2.2×10^8 kg. Given that sea water has a density of 1.1×10^3 kg/m^3, what is the minimum volume of water the tanker must displace to stay afloat?

.....

.....

(b) Explain why the volume of water displaced is greater in tropical waters than in temperate waters.

.....

(c) If the tanker is to transport oil to areas of higher temperature, the tanker must not be completely filled. Give one reason for this practice.

.....

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4.

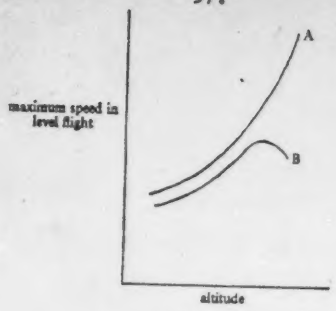

Fig. 3

(a) Fig. 3 shows the performance of a jet-engined aircraft, B, and a rocket-engined aircraft, A, at various altitudes. Account for the shapes of the two graphs.

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.....

.....

(b) Explain

why jet aircraft use more fuel when flying at a height of 8000 m than when flying at a height of 15 000 m.

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5. Fig. 4 shows a discus thrower in the process of throwing a discus.

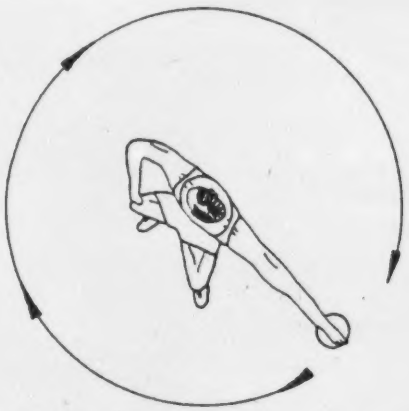

Fig. 4

(a) The discus thrower in Fig. 4 intends the discus to travel between the two black dots. Indicate on the diagram where he will have to release the discus and its path after release.

(b) What will be the effect on the flight of the discus if the thrower turns more slowly?

.....

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(c) At which moment during its flight will the discus have the greatest potential energy? Give a reason for your answer.

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PART 3

MEASURING FORCES

You have now learnt about many kinds of forces. You have seen that forces can act sideways, upwards as well as downwards and even at a distance. Sometimes it is necessary to know how big or small forces are and to compare them. To be able to do this you need to measure the forces. Since you cannot see a force you cannot measure the size of a force in the way you measure the length of a line. To measure the size of a force you must measure its effect on things. In Unit H_1 you learnt how to use a FORCEMETER and in fact calibrated your own. To remind you here is a summary of how force is measured with a FORCEMETER.

SUMMARY: MEASURING WITH A FORCEMETER

1. The standard unit of force is the NEWTON, usually written as N.
2. The force of gravity is approximately 10N per kilogram of mass. Therefore a MASS of 100g is attracted by the Earth's gravity with a force of 1 NEWTON. This is its weight. On Earth 1kg MASS weighs 10 NEWTONS.
3. Your forcemeter measures forces as PUSHES or PULLS.

THE FORCEMETER

FORCES AND DIRECTION

Earlier in this unit (and in Unit H_1) you learnt that we represent the direction that a force pushes or pulls in by an ⟶ . All things, such as forces, where direction is an important part of the measurement, are shown with an - ⟶ and we call them VECTORS. An example would be a force of 2 Newtons pushing downwards which we would show like this ↓ 2N.

Remember there are many things that have no direction in their measurement. These are called SCALARS. An example of a scalar would be 2kg of sugar. (People at your local store would think you were very strange if you asked for 2kg of sugar going East!)

Activity: 6. Adding Vectors Together

You already know how to add SCALARS.
For example 2kg of sugar + 3kg of sugar = 5kg of sugar.
However with vectors you have got to take the direction into account. Imagine 2 boys are pulling in opposite directions on a rope.

If boy A pulls with a force of 50N and boy B pulls with a force of 75N in the opposite direction, which boy will exert the greater force? Also, how would an observer know which is the stronger boy?

In this case it is quite easy for you to work out in your head the result of the "tug-o-war" between boy A and boy B. This is how you could do it on paper.
First we represent the boys' forces with arrows like this

Notice that the points of the arrows give the directions that each boy pulls and the length of the arrow is proportional to the amount of force used (in newtons). (check by measuring them)
In this case we've made the 50N arrow 5cm and the 75N arrow 7½ cm.
Thus the scale is: 1cm represents a force of 10N.

As you no doubt realised boy B is the stronger and will succeed in pulling boy A in his (B's) direction. We know that 50N of B's force will be balanced by A's resisting force of 50N, therefore the resulting force will be 25N. We call this the RESULTANT and would show it as:

RESULTANT 25N

How long would you expect this arrow to be?

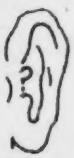
Now do the following Exercise on Vectors and Scalars.

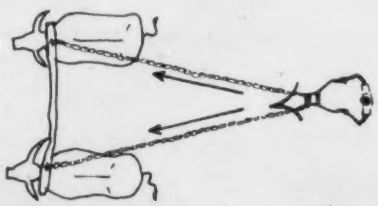
Exercise 11.

1. Give 3 example of SCALARS.
2. Give 3 example of VECTORS.
3. A man pushes a car with a force of 200N but friction resists his efforts with a force of 100N.
   Will the car move? Draw a vector diagram to show the resultant.

VECTORS AT AN ANGLE TO EACH OTHER

So far you have looked only at vectors that act in opposite directions to each other. What do you think would happen if you had two vectors acting at an angle to each other.
Suppose you had two oxen pulling on a plough, as in the diagram below.
What direction would the plough move?
How could you determine the size of the resultant force?
Discuss this with your teacher.





Now you will build a simple apparatus on which you will be able to balance forces against each other and measure the resultants of forces acting at an angle to each other.

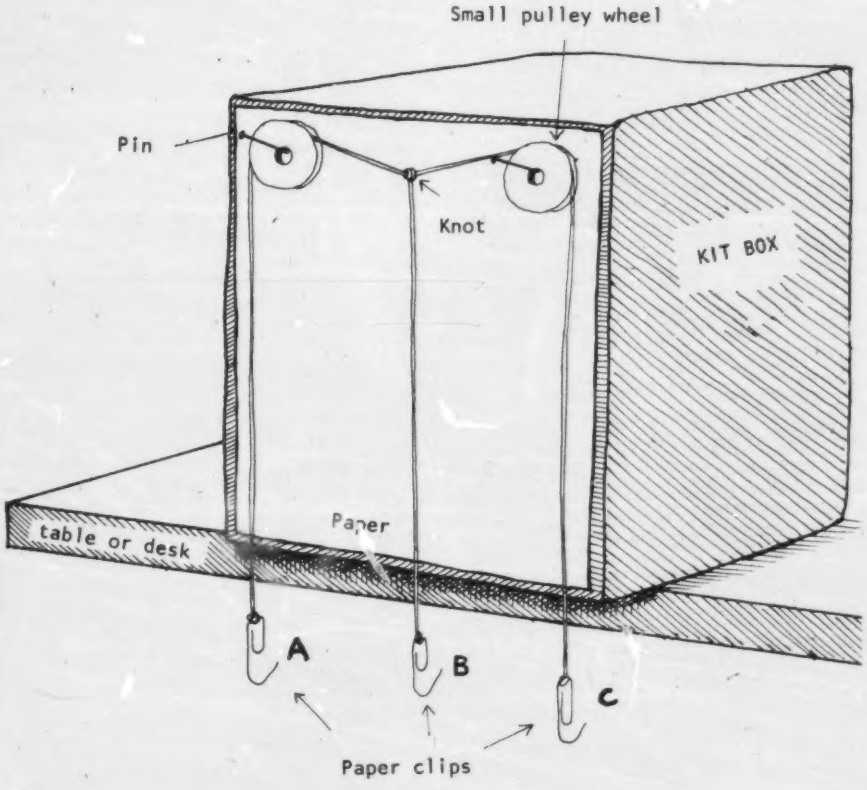
Experiment 8.: LOOKING AT FORCE VECTORS

You will need:

2 pins
2 pulley blocks
20 x 5g masses
about 30cm string
1 large boiling tin $\frac{3}{4}$ full of water
1 small boiling tin (empty)
3 lengths of string each 50cm long
3 paper clips
a kit box or other small cardboard box
a sheet of blank paper.

a. Cut your short string into 4 pieces and make up 4 separate bundles of masses containing 3, 4, 5, and 8 5g masses. What forces will these bundles cause when acting as weights?
b. Stand your cardboard box on its end (see diagram) and put the flat bottom level with the edge of your desk. Place your large boiling tin ($\frac{3}{4}$ full of water) inside to hold the box in place.
c. Take your pulley blocks apart. Keep the small pulley wheels for the experiment and store the left over bits in your empty small boiling tin so that after the experiments you can rebuild the pulley blocks.
d. Tie an end from each of your 3 50 cm strings together into one knot. Tie a paper clip, bent slightly open (see diagram) onto each of the 3 free ends of the strings.
e. Pin your blank piece of paper up onto the box, putting the pins in the top corners. Make sure that the paper is hanging straight and that the pins are stuck in level.

f. Put the 2 small pulley wheels on the pins and then put the strings round the wheels (as in diagram) with the middle string (B) hanging down between the two wheels. Make sure that the wheels are not scraping against the box and will run freely. On the other hand do not put them so close to the pin heads that they will fall off easily or bend the pins downwards.



g. You will not put anything on the middle string (B) at first but it is still useful as a marker.

h. Hang the two bundles of 3 and 5 5g masses on the paper clip of string A and hang the bundle of 8 5g masses from the clip on string C. Check to see that the wheels will move freely by pulling gently first on string A and then on string C.
Are the forces balanced?
Record your observations in the table which you will copy down from your teacher.

i. Now remove the bundle of 5 5g masses from A leaving only the 3 5g masses on it. Then remove the 8 5g mass bundle from C and put the 4 5g mass bundle on it.
Are the forces balanced?
Record what happens.

j. Now hang masses on B but still keep your bundles of 3 5g masses on A and 4 5g masses on C. Try first with the 8 5g mass bundle and then with the 5 x 5g mass bundle on B.
Are the forces balanced?
Record what happens.

k. Look at the shape that your strings make in the middle of the box. Check that the wheels are not sticking by pulling gently on each of the strings and then seeing if they return to the same shape.

l. Take your pen and make a dot exactly under where the knot that ties the 3 strings together rests. Then make a dot exactly under each string as far from the knot as you can get.

m. Take your apparatus apart now but keep your paper with the dots (and remember to put your pulley blocks back together).

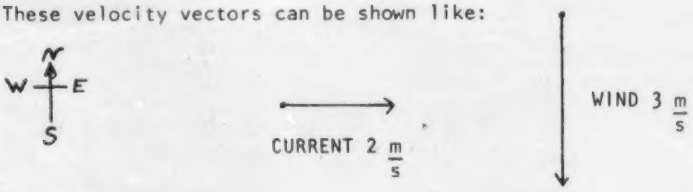
n. Using the table you have made do Exercise 12.
Discuss the results with your teacher.

ANOTHER VECTOR

Now you have seen how to add force vectors. The combined effect of the added forces is always called the RESULTANT force. You will find that you can add any vectors together by this method BUT they must be of the same kind!

Another vector is VELOCITY. This is how quickly something travels in a certain direction. We normally measure VELOCITY vectors in METRES per SECOND (written $\frac{m}{s}$ or m/s or ms^{-1}).
Examples showing direction would be:
A wind blowing from the NORTH at $3\frac{m}{s}$ or a current flowing in a river at $2\frac{m}{s}$ EAST.

These velocity vectors can be shown like:

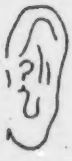


NOTE: You can add velocity vectors to each other ONLY if their units are the same. And of course you cannot add Force and Velocity vectors together!

Exercise 13.: Adding velocity vectors.

To see if you can understand velocity try this problem:
An Air Zimbabwe Viscount aircraft sets off to fly from Harare due South to Masvingo. The plane flies at a speed of 500 km per hour but a strong wind, is blowing at a speed of 100 km per hour from the West.

What would the resultant speed of the Viscount be?
Which direction would the aircraft be flying in?



Using the method you learned in Exercise 12. try to work this problem out and then DISCUSS the answer with your teacher.

BALANCING FORCES

When you measured weight with your forcemeter you measured how much the Earth's gravity causes the spring in the forcemeter to stretch. Another way of measuring weights or other forces is to balance two forces against each other.
Remember the work that you did in H_1, balancing forces?
Now you will do some experiments to measure force you discovered earlier in this unit by balancing them.

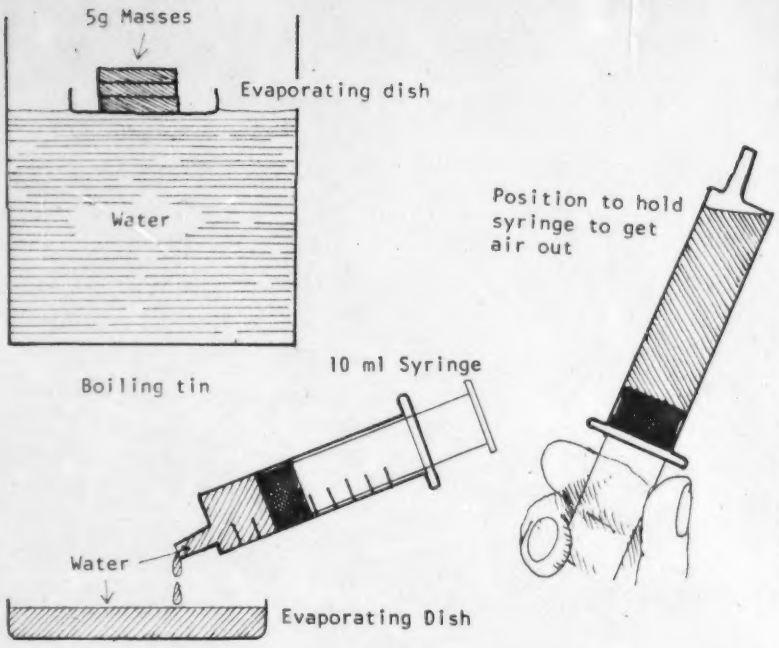
Experiment 9 : BALANCING THE FORCE OF FLOTATION

You have already looked at the uses of upthrust forces in liquids to float objects. However, if you wanted to know how much a safe load for a boat would be, you must be able to measure this force. As a boat is loaded it pushes more and more water out of the way as it settles deeper and deeper. How does the mass of this DISPLACED water relate to the boat and its load?

You will need:

a large boiling tin
5g masses
a big syringe (10ml)
an evaporating dish
some water

a. Fill your large boiling tin about $\frac{3}{4}$ full of water.
b. Put your empty evaporating dish on the surface of the water like a little boat. Try to get it not to touch the sides of the boiling tin.
Record what happens.
How well does it float?



c. Now pile the 5g masses CAREFULLY in the centre of your evaporating dish one at a time.

d. When the water is level with the top of your evaporating dish STOP before it comes in and sinks the dish.

e. Record the number of 5g masses you could pile on just BEFORE the evaporating dish sinks.

f. Take the evaporating dish out and shake it dry. Now you are going to measure exactly how much water is neede to fill it up.

g. Suck water into your 10ml syringe, way past the full 10 ml mark. (Use the water from the boiling tin.)

h. Turn the syringe upwards (as in diagram) and squeeze the air and water slowly out until your plunger bottom is exactly on the 10ml mark.

i. Then turn the syringe to point downwards and carefully push that 10ml of water out and into the evaporating dish. Repeat this until the evaporating dish is filled with water to the brim. Record what volume of water is needed.

j. Copy down the table your teacher has put on the board and answer Exercise 14.

Discuss your results with your teacher.

Balancing masses that are different to each other.

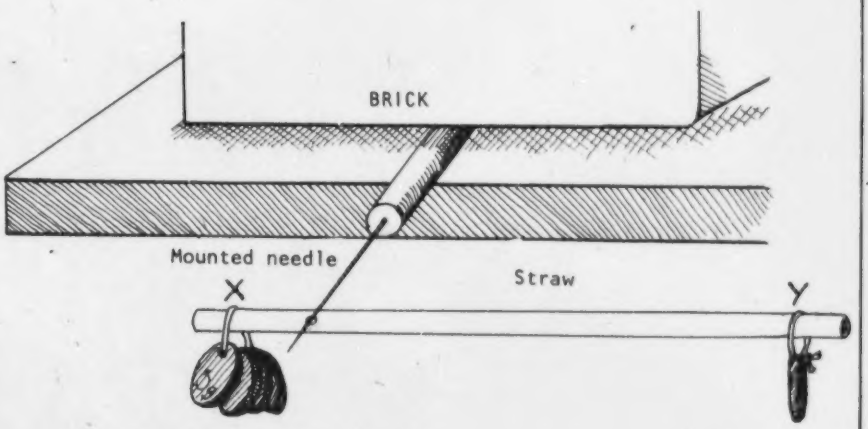
In Unit H_1 you constructed a simple balance. Now you will take that idea a little further to see if it is possible to balance a mass against a smaller mass.

Experiment 10 : BALANCING MASSES

You will need:

a brick
a drinking straw
a mounted needle
some string
your burner
5 x 5g masses.

a. Heat your mounted needle for a few seconds over your burner and then burn a small neat hole in your drinking straw, 7cm from the end (see diagram). Note the hole you burn must not be so big that it breaks the drinking straw but it must be big enough to let the mounted needle go through easily when cold.



b. Make a bundle of 4 x 5g masses and put a small loop of string through a single 5g mass.

c. Place your mounted needle under the brick at the edge of your desk.

d. Then put the straw on the needle using the hole near the end (see diagram).

e. Hang the 1 x 5g mass from the long end and the 4 x 5g mass bundle from the short end. Slide them both up and down until they balance. We will call these points X and Y.

f. Copy down the table your teacher has on the board.

g. Measure the distance from the masses on the short side (X) to the balancing needle. Measure the distance from Y (long side) to the needle.

h. Put your measurements in the table that you got from your teacher and repeat the experiment for 3 x 5g and 1 x 5g bunches.

i. Now do Exercise 15.

MOMENTS

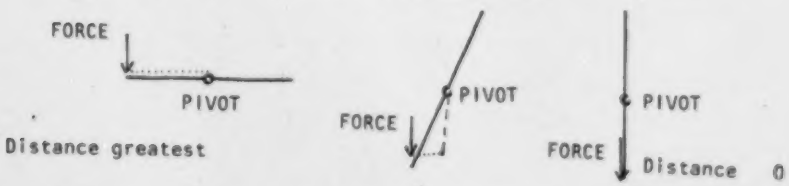
In the last experiment you probably noticed that the weights on the ends of the straw make the straw turn one way or the other depending which one was exerting the greater force. We call these turning forces MOMENTS.
Moments always turn about a fixed point, in this case your mounted needle. We call this fixed point a PIVOT.

You may have also noticed that the turning force on the straw (when it was horizontal) seemed to increase the further the weights moved away from the pivot. Because this is so we always measure moments as follows:

☆☆☆

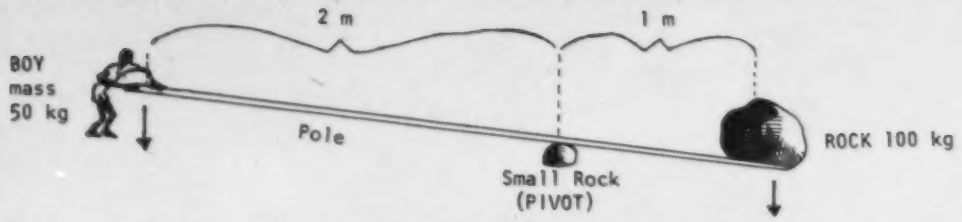
MOMENT = Force (N) x distance to the pivot (m) (MEASURED PERPENDICULAR TO THE DIRECTION OF THE FORCE)

Notice in the diagram below that the MOMENT = 0 when the force direction is no longer perpendicular to the pivot.



Now fill in the last blank column from Experiment , Exercise 15. and discuss the results with your teacher.

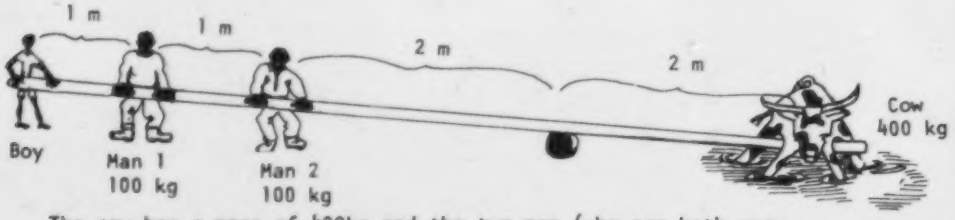
EXAMPLE



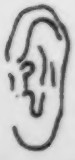
In the above diagram, the weight of the big rock (the force of gravity on it) holds it down. This weight is 1 000N. The big rock's weight acts at a distance of 1m from the pivot (little rock). The MOMENT of BIG rock is 1 000N x 1m = 1 000Nm.
Note the boy only has 50kg mass so his weight (Force) is 500N.
But he is 2m from the pivot point so his MOMENT will be:
500N x 2m = 1 000Nm.
Thus the boy's applied force just by hanging on the pole gives him a moment equal to that of the rock. So with just a little extra force he should be able to move the big rock which is twice his mass.
Discuss this with your teacher.
Now try this problem.

Exercise 16: SAVE THE COW

Below is a picture of two men trying to lift a sick cow out of the mud where it is stuck. The cow is too exhausted to move in any way that can help the men but the mud holds it very lightly and so will not hold it back very much.



The cow has a mass of 400kg and the two men (who are both very fat) each have masses of 100kg.
Is it necessary to have the boy on the end of the gum-pole?
If so, what is the very least that he should weigh ?
What force is keeping the cow in the mud?
What other force is probably helping to keep the cow in the mud?
Try working this problem out and then discuss it with your teacher.

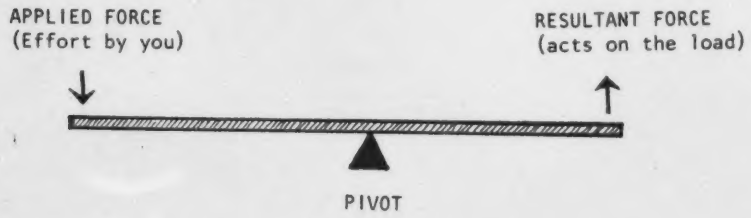


MORE ABOUT BALANCING FORCES

You have seen a smaller force can be used to match (balance) a larger force. Knowing this we can then apply this knowledge in a useful way.

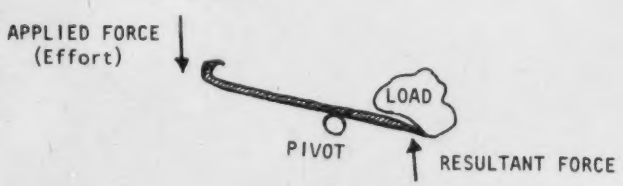
THE LEVER

The most common tool used to overcome a larger force by applying a smaller force is the LEVER. All levers have the following basic structure.

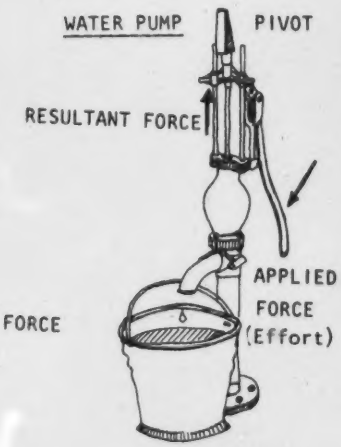


Here are EXAMPLES of some LEVERS you may have seen in everyday use:

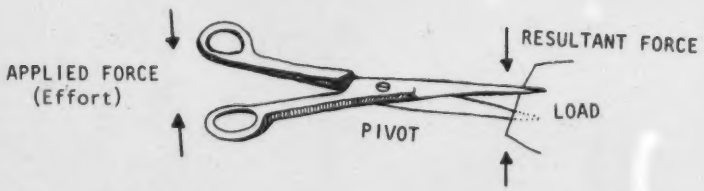
CROW BAR



WATER PUMP

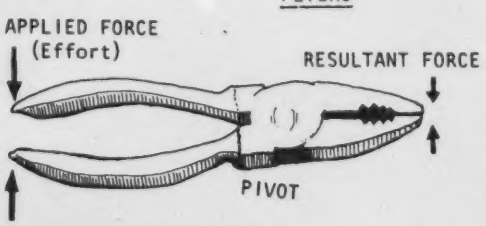


SCISSORS



SHOVEL

PLIERS



WHAT MAKES A LEVER WORK?

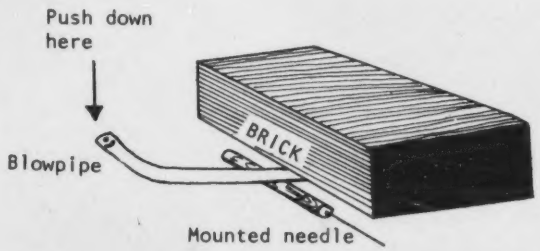
When a force is applied at one end of a lever in one direction, you get a RESULTANT FORCE occurring on the other side of the PIVOT in the opposite direction. The amount of RESULTANT FORCE produced and the amount of APPLIED FORCE needed depends upon where the PIVOT point is.
You will now use a small lever.

Experiment 11 : USING A LEVER

You will need:

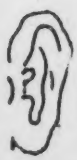
a brick
a mounted needle
a metal blow pipe

a. Put the straight end of your blowpipe about 1½cm under the brick.
b. Then place your mounted needle under the blowpipe and about 1cm from the edge of the brick (see diagram).

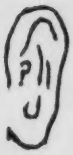


c. Push down with your hand on the bent end of the blowpipe. How much force do you need to apply?
d. Now repeat your actions, moving the mounted needle further from the brick and nearer to the end of the blowpipe that you are pushing down. How much force do you need now?

Discuss this with your teacher.

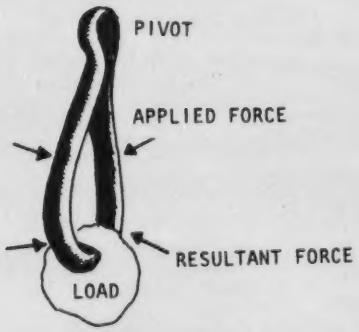


MORE LEVERS

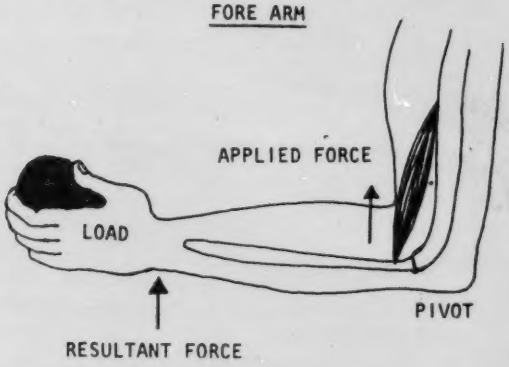


Not all levers have the pivot in the middle and the LOAD and EFFORT on opposite ends. Here are some different levers to discuss with your teacher.

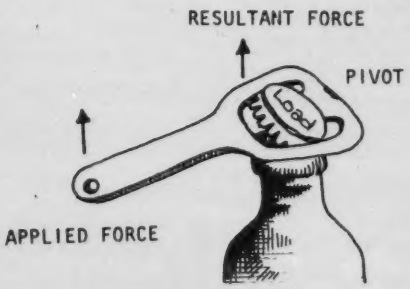
TONGS



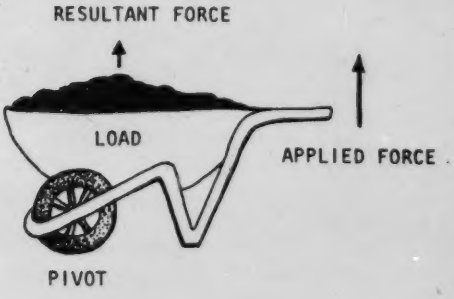
FORE ARM



BOTTLE OPENER



WHEEL BARROW



CENTRE OF MASS

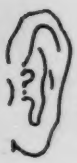
All objects are made up of particles, Each of the particles has a mass and therefore is attracted by the force of the earth's gravity. IF all of the particles are of the same substance and the object that they make up is a regular shape, then we say that the CENTRE of MASS of that object is in the centre of that object.
You will now do an activity that will help you to understand this.

ACTIVITY 7 : ESTIMATING CENTRE OF MASS

Your teacher will give you:

1 x 5g mass
1 white polystyrene cube.

Look at your polystyrene cube. It is a regular shape and is obviously completely made up of the same material. Also look at a 5g mass. It is a different shape and a different material but could you say that it too is regular in shape?
Where do you think the centre of mass would be in each case?
Now look at your pen.
What is it made up of, and is its shape regular?
Where do you think its centre of mass will be?
Try balancing it on your finger and discuss these 3 objects with your teacher.



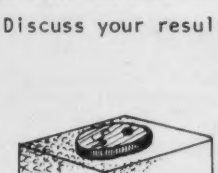
Not all objects are made up of the same kind of particles and so, depending where those particles with the greatest mass are located, the CENTRE of MASS will be shifted somewhere away from the centre of the object. Remember how you found the Centre of Mass in animal shapes in Unit H_2. You will now carry out an experiment to see how the Centre of Mass can shift.

EXPERIMENT 12 : CHANGING CENTRE OF MASS

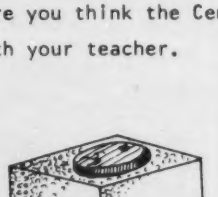
You will need:

6 x 5g masses
1 white polystyrene cube
some "stikistuf"
large boiling tin three quarters full of water

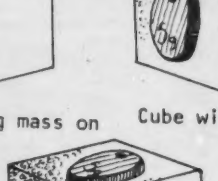
a. Take your polystyrene cube and try floating it in different ways on the water in your tin. Does it seem to prefer any particular side to float on?
b. Take you cube out, dry it and, with one small blob of "Stikistuf", stick one 5g mass onto the middle of one face of the cube.
c. Return it to the water and note if it seems to "prefer" to float a certain way. Has the centre of mass changed? If so, where do you think it is now?
d. Repeat this procedure using 2, 3 and 4 of the 5g masses (see diagrams). In each case make a note of the behaviour of the cube and work out where you think the Centre of Mass is. Discuss your results with your teacher.



Cube with one 5g mass on



Cube with two 5g masses on



Cube with three 5g masses on

CENTRE OF MASS AND STABILITY

What is stability?

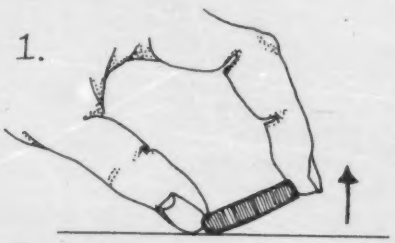
At some time in your life you must have tipped backwards on a chair until it balanced only on its two back legs. Balanced like that but not moving you would have been in EQUILIBRIUM. However, if you leaned further back you probably fell over, chair and all. That was because you and your chair had become UNSTABLE. If, on the other hand, you had returned your chair to stand properly on all 4 legs, that too was EQUILIBRIUM but much more STABLE. You will now do an activity to help you understand the different states of EQUILIBRIUM.

EXPERIMENT 13: Centre of Mass & Equilibrium

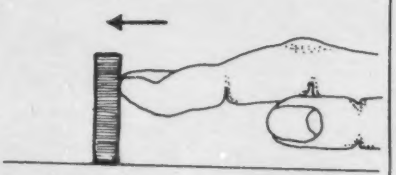
You will need a 5g mass (make sure that you have one with smooth edges). Look at your 5g mass.
Where do you think its centre of mass is located?

a. Lay the 5g mass flat on desk (see diagram 1). Raise one end of the 5g mass and then let it go. What happens?

1.

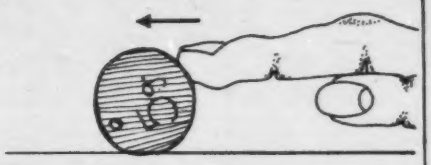


2.



b. Stand the 5g mass on its edge (see diagram 2). Push it slowly with your finger. What happens?

3.



c. Again, stand the 5g mass on its edge (see diagram 3). This time push it slowly at the edge. What happens?

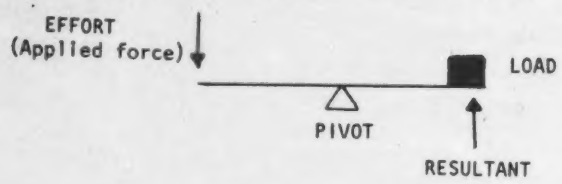
Now do Exercise 17.

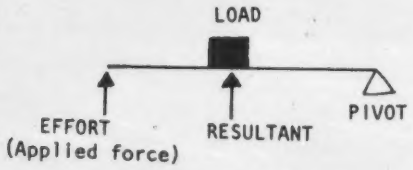
SUMMARY: MEASURING AND BALANCING FORCES

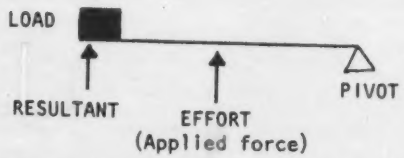
1. Forces are VECTORS because they have amount and direction.
2. Force vectors can be represented by an ⟶ where the direction of the arrow is the force's direction and the length of the arrow relates to the amount of force (e.g. long arrow big force).
3. VECTORS (any kind as well as force) can be added by drawing. When there are two vectors going in different directions, as long as their units are the same they can be added by drawing them tail to tail and constructing a PARALLELOGRAM to find the RESULTANT.
4. When two forces acting at a point have equal amounts (of push and pull) but are in opposite to each other in direction, then we say they are BALANCED. When this happens no movement OCCURS.
5. As an object is immersed in water it DISPLACES (moves aside) an amount of water equal to its own MASS.
6. Two MASSES can be made to balance each other (reach a position of no movement) if they are hung on opposite sides of a fixed point called a PIVOT.
7. A LEVER is a device whereby a FORCE is applied to one point as EFFORT and then this force acts through a PIVOT point to move another point where a RESULTANT FORCE then acts on a LOAD.

Continued ...

8. The 3 basic levers are:







9. In a LEVER the Forces on one side of the PIVOT would turn that lever in one direction and can be balanced by forces on the other side of the pivot point turning the lever in the other direction. On each side of the pivot the forces are acting as MOMENTS. All MOMENTS are made up of FORCE x DISTANCE to PIVOT. (Note: this distance is measured perpendicular to the direction of the force.) For a lever to be balanced the MOMENTS on both sides must be equal in size but opposite in direction of action.

10. The centre of mass of any body is the point within that object where the most mass is concentrated.

11. The 3 states of Equilibrium are:

    a. STABLE EQUILIBRIUM - where a disturbing force will raise the object's CENTRE OF MASS but will return to its original position once the disturbing force is removed.

    b. UNSTABLE EQUILIBRIUM - where a disturbing force will lower the object's CENTRE OF MASS until it reaches a point outside the object's base. It will then fall over or lose its EQUILIBRIUM and will not return to i its original position.

    c. NEUTRAL EQUILIBRIUM - where a disturbing force will not affect the object's CENTRE OF MASS and the object may be displaced but just into a similar equilibrium position.

E.Q.

EXAMINATION QUESTIONS

Here are more Examination Questions for you to try from past A.E.B. papers.

Again the lines are just to give you an idea of how much to write. Please write your answers in your exercise books.

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1. In Fig. 1 the symbol ● represents a boat heading due east at 10 km/h relative to the water, whilst the water flows due north at a speed of 5 km/h.

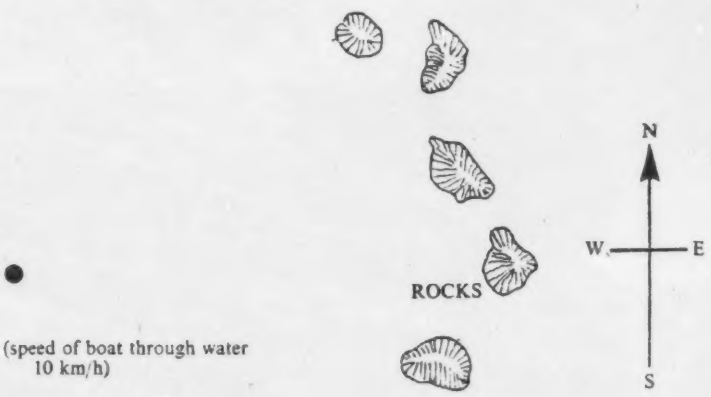

Fig. 1

Show by drawing on the diagram whether or not the boat will pass between the rocks. (You should state clearly the scale you have used.)

2.

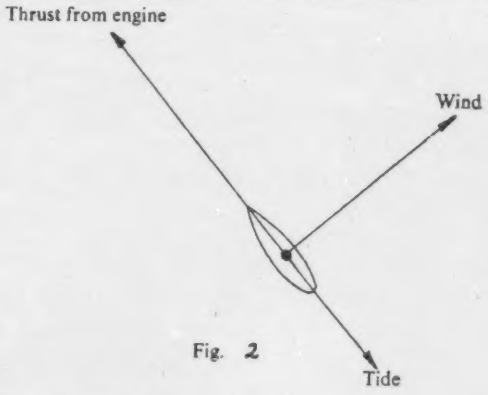

Fig. 2

Fig. 2 shows three forces acting on a boat.

The directions of the arrows show the direction in which the forces act and the lengths of the arrows are proportional to the magnitudes of the forces.

Show on the diagram the direction in which the boat will travel.

Show clearly how you arrived at your answer.

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3. Fig. 3 shows a decoration which can be hung by a thread from the ceiling.

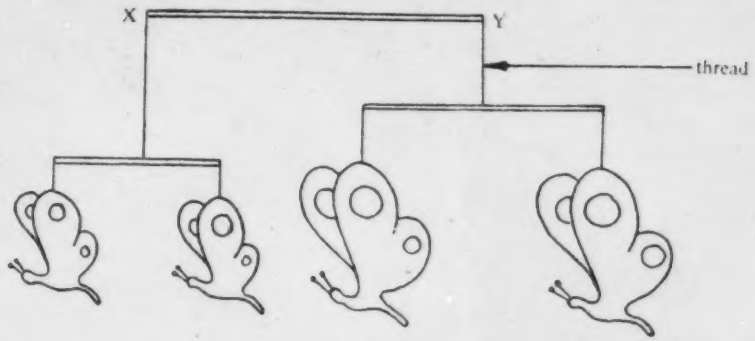

Fig. 3

Each of the big butterflies weighs twice as much as each of the small ones. Mark the point at which the rod XY must be suspended in order that it shall hang horizontally. Ignore the weight of the rods and threads.

Show how you obtained your answer.

4. A specimen of moon rock weighed 10 N on the Moon's surface. How much would it appear to weigh on the Earth's surface when using,

(i) a spring balance,
(ii) a beam balance calibrated in newtons?

Give a reason for your answer. (The Moon's gravity is one sixth of the Earth's gravity.)

5. A rowing boat is designed to displace 0·3 m^3 of water when safely loaded. The boat itself has a mass of 75 kg, and two men of masses 90 kg and 85 kg step into the boat. Calculate the maximum mass of cargo that the two men can take with them without loading the boat unsafely. (1 m^3 of water has a mass of 1000 kg).

6. A submarine attempts to recover a lost object from the sea bed. This object has an apparent weight of 10 000 N. The sea water has a density of 1100 kg m^{-3}. What volume of water (to the nearest cubic metre) must the submarine remove from its ballast tanks in order just to lift the object? (Assume that a mass of 1 kg weighs 10 N.)

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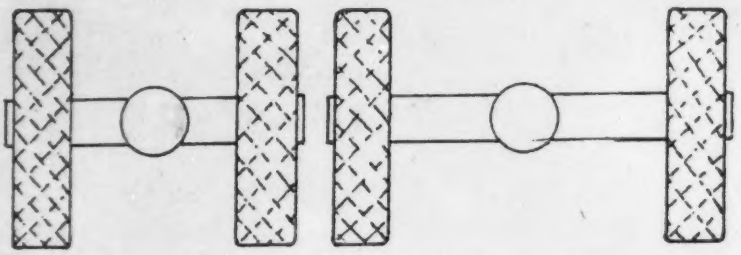
7. Fig. 4 shows the back wheels of a tractor adjusted for ploughing on flat ground and on hill slopes.



Adjusted for flat ground Adjusted for hill slopes

Fig. 4

(a) Explain why the distance between the wheels should be increased for hill slopes.

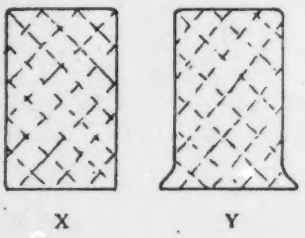


Fig. 5

(b) Fig. 5 shows the profile of normal tyres and those used on soft mud or sand. Explain why tyres with a profile shown by Fig. 5 Y are preferred for use on soft ground.

8.

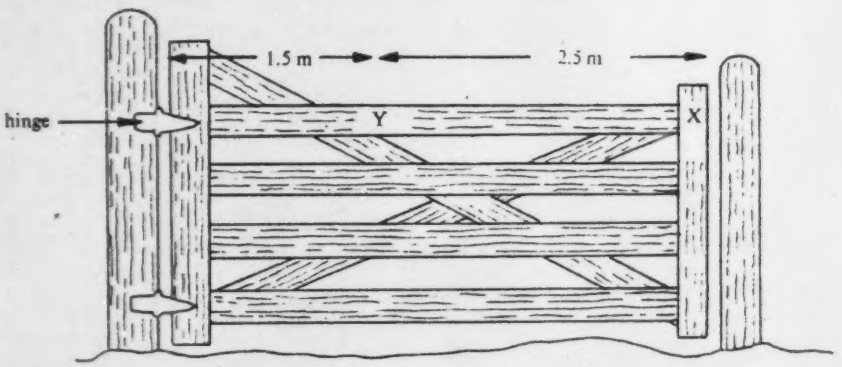


Fig. 6 shows a farm gate. Fig. 6

If a force of 50 N has to be applied at point X to open the gate, calculate the force that must be applied at point Y in order to open the gate.

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PART 4

WHAT IS PRESSURE

You already know that pressure is something to do with force because in the syringe experiment that you did in UNITS C_2 you found that air pressure had a force that moved the syringe plunger. You will now do a short activity that will show you more about pressure.

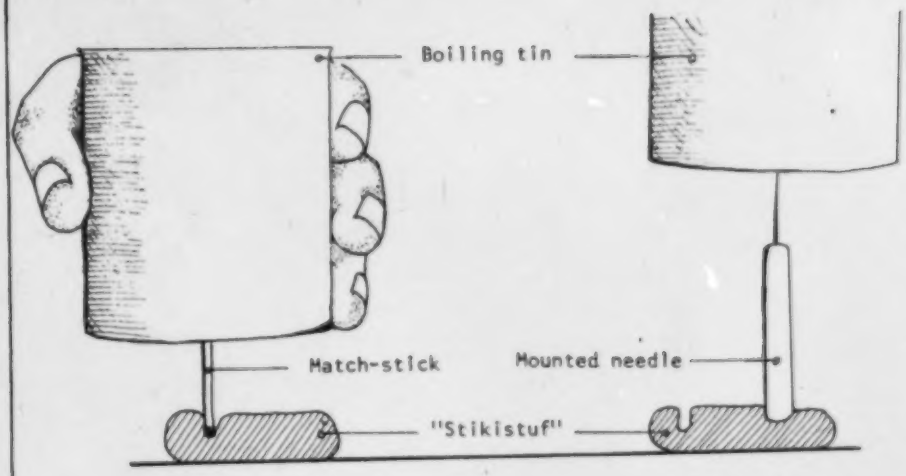
EXPERIMENT 14 : THE EFFECT OF PRESSURE

You know that to press on something is to push down on it, wo you will use a pushing down activity to help you understand pressure.

You will need:

a blob of "stikistuf" 1cm x 1cm and about ½cm thick
your large boiling tin nearly full of water
a match stick
a mounted needle

a. Stretch and roll your "stikistuf" to make it soft and then shape it into a square 1cm x 1cm. Also make sure that it is about ½cm thick.
b. Stick this square to your desk and make sure that the top of the "stikistuf" is as flat as possible. (To do this, press it lightly onto the desk and then turn it over).
c. Take your match stick and put it lightly, head first, onto the "stikistuf".
d. Holding your large boiling tin full of water very carefully, put it onto the match stick so that the match head sinks into the blob of "stikistuf". Be careful that the only force on the matchstick comes from the weight of the tin full of water. (See diagram.)



e. Repeat this now with the mounted needle. Make sure that the point is under the tin and the back of the handle is pushing into the "stikistuf". Also make the hole next to the one made by the matchstick.

f. Compare the two holes you have made in the "stikistuf" and then do Exercise 18.

DEFINITION: We say that PRESSURE is the FORCE that presses directly onto a UNIT AREA.

☆☆☆

<u>therefore</u>: $\text{PRESSURE} = \frac{\text{FORCE}}{\text{AREA}} = \frac{\text{N}}{\text{m}^2}$

<u>NOTE</u>: $\frac{\text{N}}{\text{m}^2}$ is the SCIENTIFIC UNIT for measuring pressure but there are many other units in use. Below you can see how to convert from one kind of unit to another.

$1\ \frac{\text{N}}{\text{m}^2} = 1$ Pa (called a Pascal) $= 1.45 \times 10^{-4}\ \frac{\text{lb}}{\text{in}^2}$ (pounds per square inch.)

Some everyday pressures

The pressure that the atmosphere exerts on the surface of the Earth is called: an ATMOSPHERE.

1 ATMOSPHERE = 1 BAR = 14.69 $\frac{lb}{in^2}$ = approx. 100kPa (kilopascals)

Car tyre pressures are usually measured in $\frac{lbs}{in^2}$ so

25 $\frac{lb}{in^2}$ (a average sort of pressure for car tyres) = 172.4 kPa

which is roughly 1.72 Bars.

AIR PRESSURE

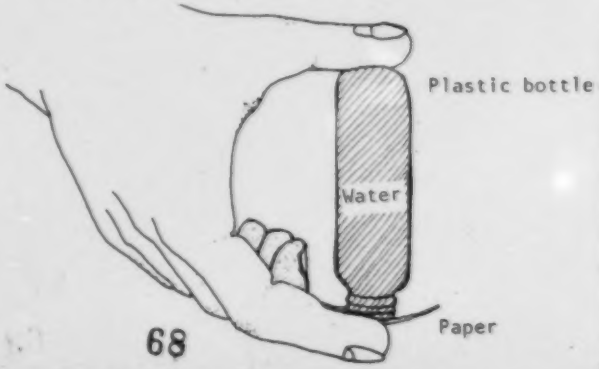
You know that there is air all around you.
Does it exert any pressure on you and other objects?
Think back to your Unit C_2 and the activity that you did with the suckers. Now do the following Experiment.

EXPERIMENT 15 : ATMOSPHERIC PRESSURE

You will need:

a small plastic bottle
a 3cm x 3cm square of paper
a boiling tin ½ full of water

a. Carefully fill the plastic bottle with water from the boiling tin. Make sure that the water is up right to the top of the bottle and there are no air bubbles trapped inside.
b. Place your piece of paper over the mouth of the bottle. Hold it in place with your finger and then turn the bottle upside down. Remember to do this over your boiling tin in case of water spilling.



c. Wait a couple of seconds for the water in the bottle to get still and then take your finger away, leaving the paper in place. What happens?

Now do Exercise 19.

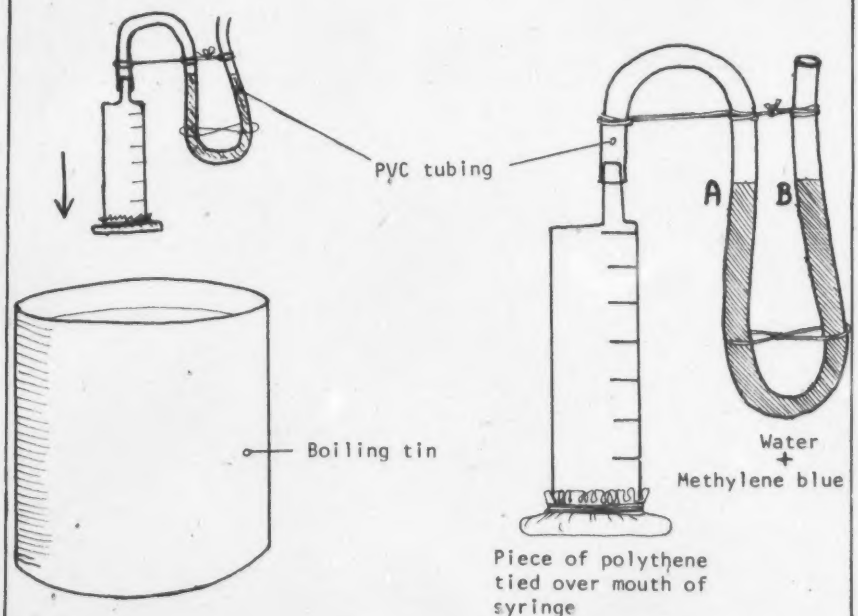
WATER PRESSURE

You have learnt that liquids exert a force on objects put in them. What do we call this force? Does this force get smaller or greater as you go deeper into a liquid?
You will now do an experiment to find out.

EXPERIMENT 16 : PRESSURE CHANGE WITH DEPTH

You will need:

25cm of 3mm I.D. PVC tubing
about 30cm of string
a piece of polythene 7cm x 7cm
a 10ml syringe
large boiling tin three quarters full of water
100ml beaker with a solution of methylene blue or potassium permanganate



a. Fold your PVC tubing into an S shape and tie it with string (see the diagram) so that the loops you have made will stay in place.

b. Fit one end of your tube now onto the nozzle of your 10ml syringe.

c. Point the syringe downwards and remove the plunger.

d. Pour your solution of methylene blue or potassium permanganate into the syringe so that the tube is filled with coloured water. (The colouring is only to help you see the water level more clearly.)

e. In this position you can insert the plunger again, gently, and push out the excess liquid. (You want to end up with the U tube only half full.)

f. When you have done this take the plunger out slowly and tie your piece of polythene (cut from an old plastic bag) over the mouth of the syringe with string. Check that it has no holes in it.

g. Look at the levels of the coloured solution in the U bend of your tube. Mark where they are.
Are they both at the same level? Why is this?

h. Now try blowing gently into the open end of the U tube.
What happens to the level on the A side. Why is this?

i. Push gently with your thumb on the polythene over the mouth of the syringe. What happens? Then slowly dip the syringe (polythene-covered end first) into the water in the boiling tin. What happens now to the levels in A and B?

Now do Exercise 20.

EXPERIMENT 17: Changes in water pressure with height

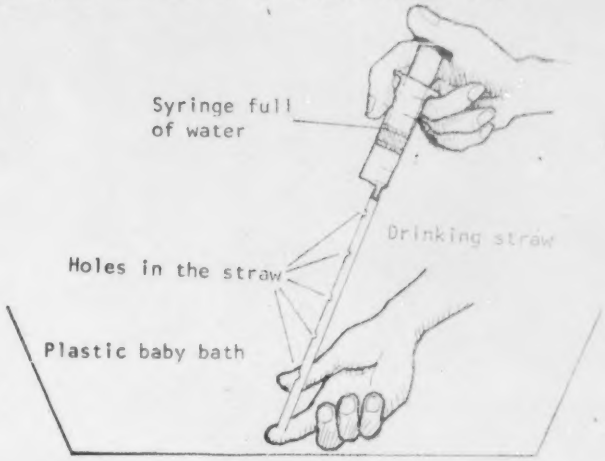
Why do you think that water tanks are always put on the roofs of houses or on hills above villages? Do this experiment to find out.

You will need:

a plastic drinking straw
a mounted needle
your burner
a 10ml syringe
a boiling tin ½ full of water
a baby bath between 6 or 8 pupils.

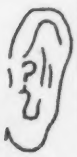
a. Heat your mounted needle with the burner and make 4 small holes (only just the size of the needle) along your drinking straw at 2cm, 7cm and 12cm and 15cm from one end. Only burn through one side of the straw.

b. Fill your 10ml syringe with water from the boiling tin. Hold your straw (see diagram) with your finger blocking the bottom and the holes towards the bottom.



Insert the syringe into the top of the straw and press the plunger down with an even motion. You must hold your straws over the baby bath to catch all the water squirting out. What happens? Does water come out all the holes in the same amount? Out of which hole does water come with the greatest pressure?

Discuss this with your teacher.



IS WATER COMPRESSIBLE?

Remember in Unit H_1 you squeezed air in a syringe. You will now do a short experiment to find out if water can be squeezed. That is, COMPRESSED.

EXPERIMENT 18 : IS WATER COMPRESSIBLE ?

You will need:

a 10ml syringe
a boiling tin ½ full of water.

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a. Take the syringe, pull the plunger up and block the nozzle with your finger and push the plunger down with your thumb. What happens?

b. Now fill the syringe with water and repeat the proceedure. What happens?

Discuss this with your teacher.

SOME USEFUL APPLICATIONS OF PRESSURE

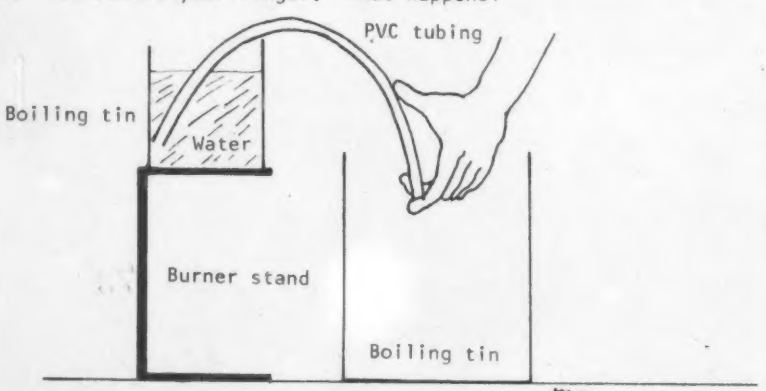
EXPERIMENT 19: The Syphon

This is a very simple method for getting water from one place to another.

You will need:

the 25cm of PVC tubing you use for the water pressure exp.
a small boiling tin full of water
your burner stand
an empty large boiling tin.

a. Place the small boiling tin full of water on the burner stand.
b. Put one end of the PVC tube into the tin making sure that it reaches the bottom.
c. Place the empty boiling tin next to the burner stand. Suck water up through the PVC tube. Put your finger over the end that you have sucked (to stop the water running back).
d. Bend the PVC tube until the end with your finger blocking it is over the empty tin and lower than the bottom of the full boiling tin on the stand.
e. Now remove your finger. What happens?



f. Now lift the lower tin slowly (taking care to keep the tube end under the water) until it is higher than the tin on the burner stand. What happens?
Put is back where it was. What happens?

g. Now pull the tube out of the water in the higher of the two boiling tins. What happens?

Now do Exercise 21.

Forces travelling through liquids

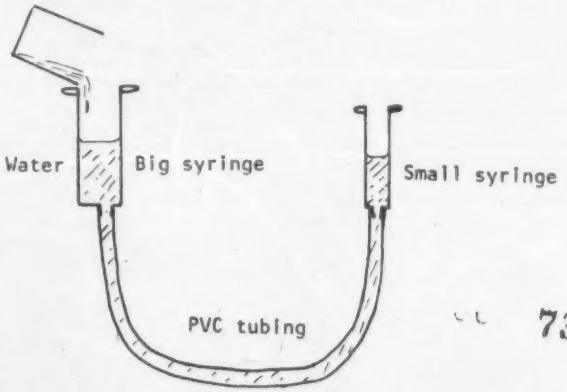
You have found that liquids cannot be compressed. This property has many useful applications. Do the following experiment to discover the way forces can travel through liquids.

EXPERIMENT 20 : AN HYDRAULIC SYSTEM

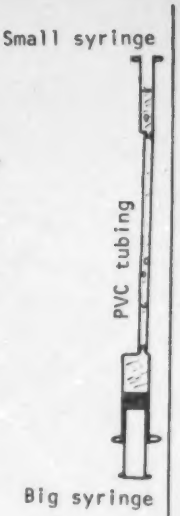
You will need:

a brick
a large syringe
a small syringe
25cm of PVC tubing 3mm I.D.
A boiling tin of water.

a. Take out the plungers and connect the syringe nozzles to each end of the PVC piping.
b. Bend your apparatus into a U shape and pour water into the large syringe until it is full. Then put its (the large syringe) plunger in (see diagram).

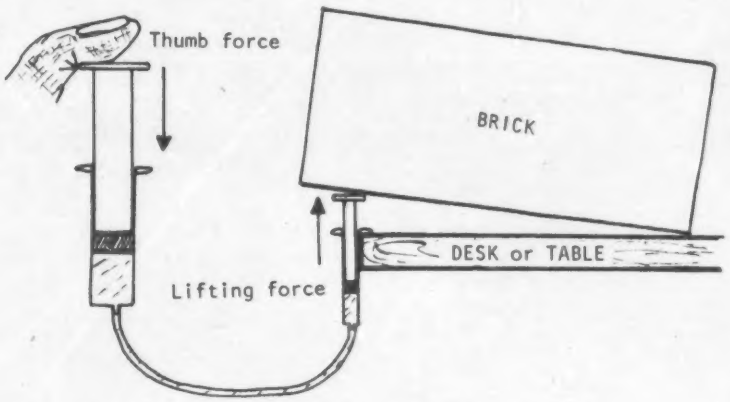


c. Staighten out the tube so that you have the large full syringe on the bottom and the empty small one at the top (see diagram). Then tap the PVC pipe to loosen all the air bubbles so that they rise to the top. Push the larger plunger in slowly until it reaches the end of the syringe and the small syringe is full or water. You will, fo course, first get quite a bit of water coming over the side of the small syringe, so hold your apparatus over your boiling tin.



d. Put the plunger into your small syringe. Now you should have the two syringes and the PVC pipe with water in them but NO air bubbles. This is called a HYDRAULIC SYSTEM.

e. Place the brick on the edge of the desk and put the small syringe under it (see diagram). Push down the plunger on the big syringe with your thumb. Note what happens?



f. Then change your apparatus around so that now the big syringe is under the brick. (N.B. At all times be careful not to let the small syringe plunger get forced out.) Push down on the small syringe now with your thumb. Note what happens?

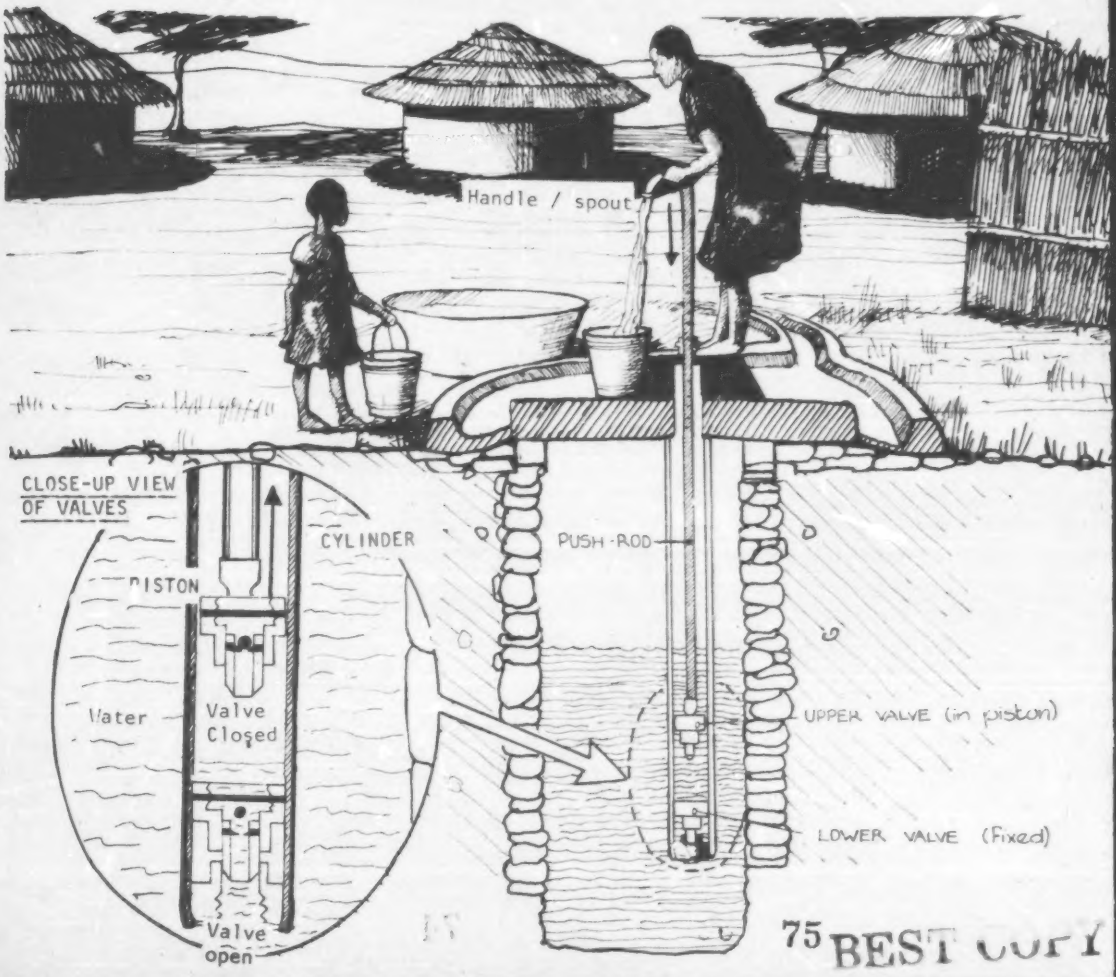
Now do Exercise 22.

THE BLAIR PUMP

The water pump in the picture below is called the "Blair" pump because it was designed by the Blair Research Laboratories in Harare. This pump has a very simple design which is that of a force and lift pump. The pump is usually used in a covered well. It can lift water up to a height of about 10 metres maximum.

HOW IT WORKS

The curved pump handle, which is also the spout for the water, is connected by a long rod to a piston which moves within a cylinder fixed below the water level at the bottom of the well. SEE THE DIAGRAM. Both the bottom of the cylinder and the piston have VALVES in them. A VALVE is a special device which allows the water (in this case) to pass ONLY IN ONE DIRECTION.



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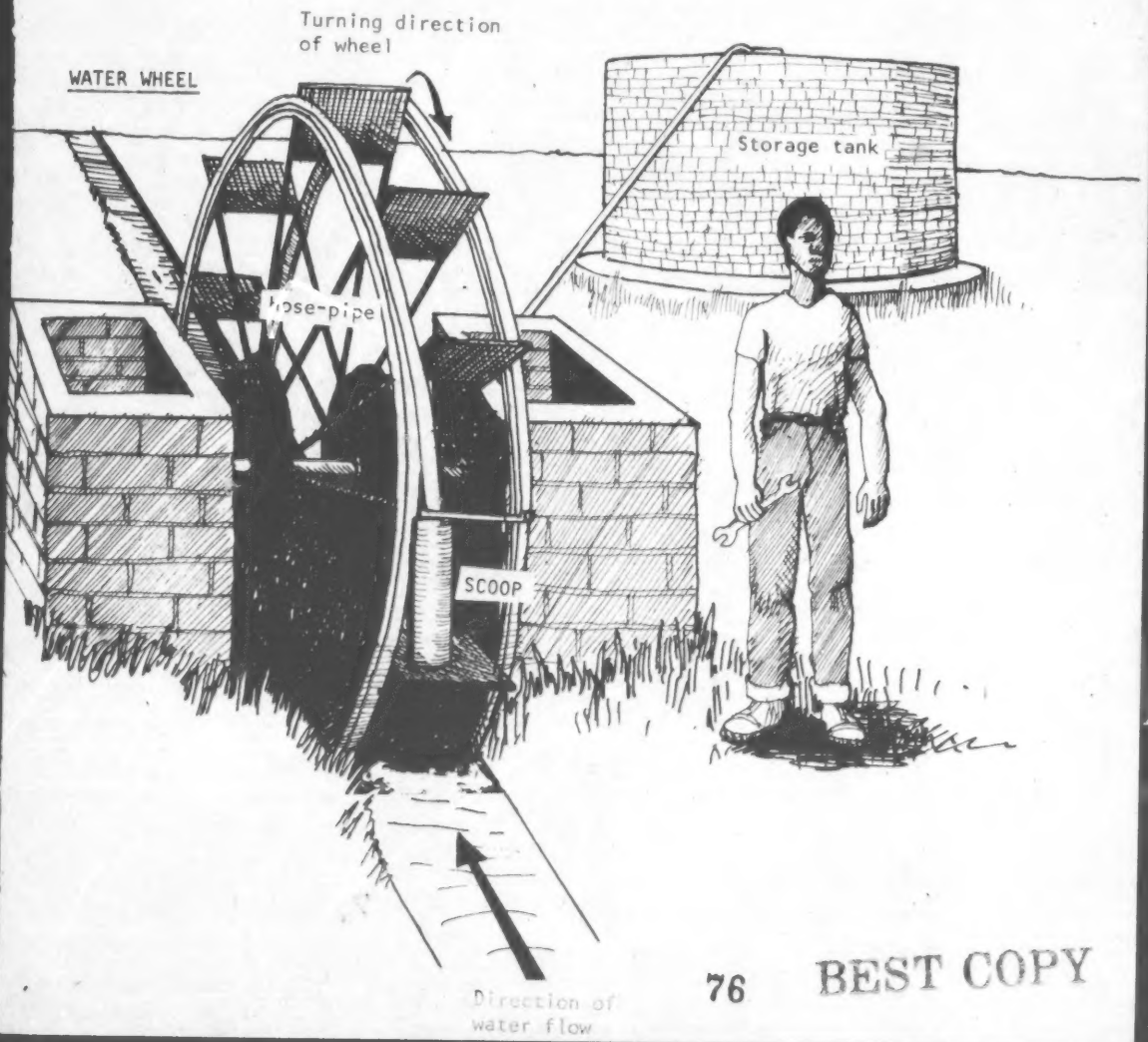
Your teacher will now show you a model of the Blair pump that has been made out of a syringe and some PVC tubing. The valves in the model are made using small ball bearings.

Then do Exercise 23.

THE SPIRAL PUMP

The spiral pump is a very simple form of water pump that can be attached to a WATER WHEEL, using the energy of the turning wheel to pump water continuously. A water wheel is a big wheel that is mounted across a stream, or irrigation channel so that the bottom end of the wheel is dipping into the water and the force of the water flow against the blades of the wheel (see diagram) causes the wheel to turn.



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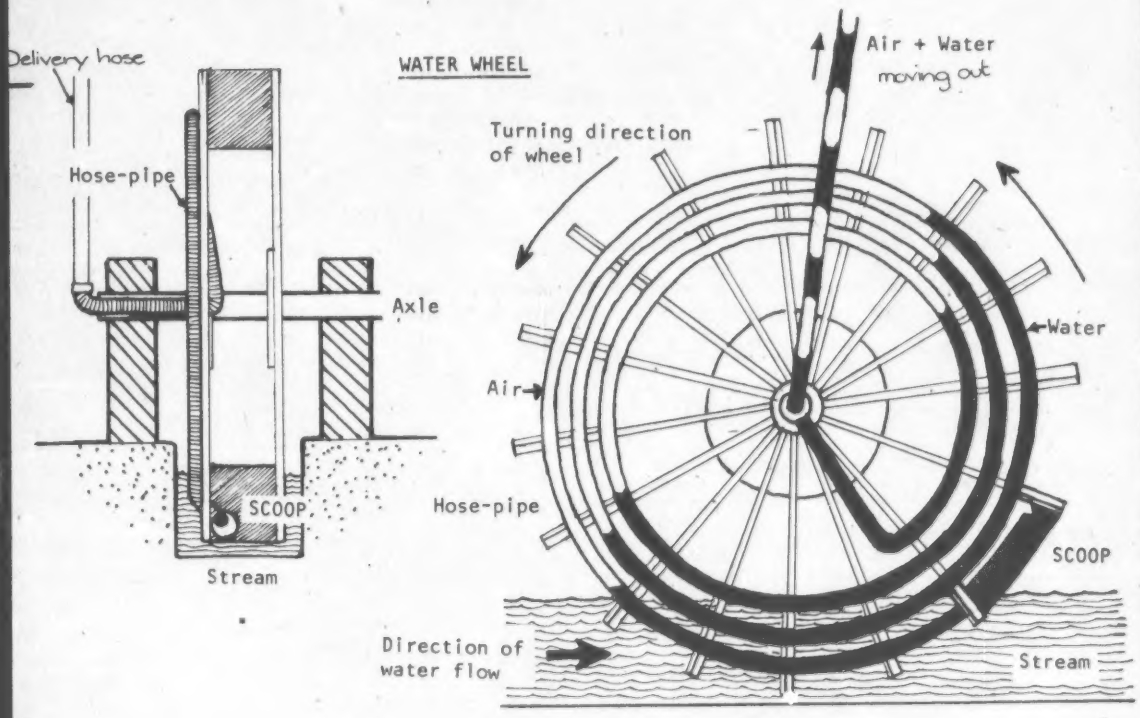
The spiral pump is made of hose pipe wound round the rim of the water wheel (see diagram) a few times and then led through the centre of the wheel's axle. From there it passes through a special joint, which allows another hose pipe to be joined on to it and that then leads up to a water tank. Where the open end of the hose pipe is on the rim of the wheel, a larger piece of plastic pipe is fitted. This is to scoop up the water when the wheel turns through the stream.



Your teacher will now show you a model of the spiral pump, which has been made using PVC tubing, a burner stand, two spatulas and some string.

Now do Exercise 24.

SUMMARY: PRESSURE

1. PRESSURE $= \frac{\text{FORCE}}{\text{AREA}} = \frac{\text{N}}{\text{m}^2}$

2. The air exerts pressure on all objects because air has mass and all the piled-up weight of the Earth's atmosphere presses on all objects on the Earth's surface.

3. Changes in air pressure are measured with an instrument called a BAROMETER.

4. Air pressure is greatest at sea level and least on the tops of high mountains because there is a greater mass of air in the atmosphere bearing down with the force of its weight at sea level. On top of high mountains there is less atmosphere above the surface of the Earth at that point.

5. The deeper an object goes into water the greater the pressure it (the water) exerts on that object.

6. The greater the height of a supply of water (e.g. reservoir or tank) above the outlet point for that water, the greater the pressure with thich the water will then come out from the outlet.

7. LIQUIDS cannot be compressed.

SUMMARY: WORK ENERGY AND POWER

In Unit H_1 you learnt that:

1. WORK is measured as FORCE x DISTANCE moved by the object because of the force.

   WORK = N x m = JOULES

2. When something has EVERGY (also measured in JOULES) it can perform WORK.

Some of the different forms of Energy are:

POTENTIAL ENERGY
KINETIC ENERGY
CHEMICAL ENERGY
HEAT ENERGY
LIGHT ENERGY
SOUND ENERGY
ATOMIC ENERGY
SOLAR ENERGY

PART 5

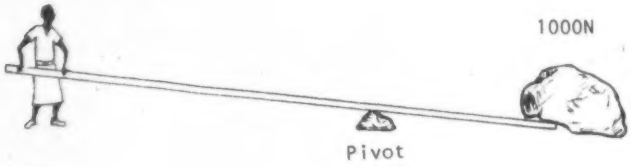
MACHINES AND JOINTS

MACHINES

Any device where you apply force at one point and get an action at another point to overcome another force is called a MACHINE. A simple lever such as a crowbar or a bottle opener is a machine. So, too, are hand-pumps and wind-mills. However complicated a machine is, it always follows the same mechanical principles. These are as follows:

Mechanical Advantage

Whenever you use a machine you do so because it gives you an advantage that you would not otherwise have. For example if a girl who weighs 500N uses a pole as a lever she is able to move a 1000N rock which normally she could not shift.



☆☆☆ We define Mechanical Advantage as (M.A.) = $\frac{\text{load}}{\text{effort}}$

In the above example the M.A. = $\frac{1000N}{500N}$ = 2

Velocity ratio

Very simply this is: VELOCITY RATIO

☆☆☆ V.R. = $\frac{\text{distance moved by effort}}{\text{distance moved by load (in the same time)}}$

If you look at the diagram above, of the girl and the rock or think back to when you moved a brick with your blowpipe, you will remember that in both cases the Effort moved a greater distance than the load.

Work output

The amount of WORK that you can get out of a machine will never be greater than the work you put in. Remember the advantage you are getting from the machine is the increased force you get out.

Discuss this with your teacher. Why is this so?

Efficiency

As you have just discussed, all the machines have a work output that is less than the work put in to them. If the work output is nearly as much as the work input this means that very little energy has been wasted. In this case, we say that the machine is very EFFICIENT. However, a machine that wastes lots of energy and thus gives a small output of work, compared to the work input, is INEFFICIENT. We measure efficiency as:

$$\text{EFFICIENCY} = \frac{\text{WORK OUTPUT}}{\text{WORK INPUT}}$$

or Remembering that Work = force x distance (that the force moves its point of application.)

$$\text{EFFICIENCY} = \frac{\text{LOAD} \times \text{distance moved by load}}{\text{Effort} \times \text{distance moved by effort}}$$

$$= \frac{\text{LOAD}}{\text{EFFORT}} \times \frac{\text{distance moved by LOAD}}{\text{distance moved by EFFORT}}$$

or

$$\text{EFFICIENCY} = \frac{\text{M.A.}}{\text{V.R.}}$$

Usually we express EFFICIENCY as a percentage (%) by multiplying by 100.

NOTE: It is impossible to make a machine that is 100% EFFICIENT.

Discuss this with your teacher.

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SUMMARY: SIMPLE MACHINES

1. Any device where you apply force at one point and get an action at another point which produces or overcomes another force, is called a machine.

2. MECHANICAL ADVANTAGE = M.A. = $\frac{\text{LOAD}}{\text{EFFORT}}$

3. VELOCITY RATIO = V.R. = $\frac{\text{DISTANCE MOVED BY EFFORT}}{\text{DISTANCE MOVED BY LOAD (in the same time)}}$

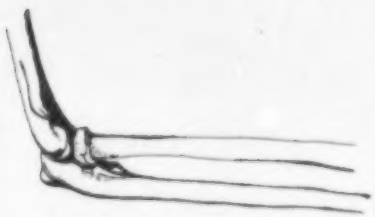
4. EFFICIENCY = $\frac{\text{WORK OUTPUT}}{\text{WORK INPUT}} = \frac{\text{LOAD} \times \text{DISTANCE MOVED BY LOAD}}{\text{EFFORT} \times \text{DISTANCE MOVED BY EFFORT}} = \frac{\text{M.A.}}{\text{V.R.}}$

SUMMARY: JOINTS & MUSCLES

This is to add to what you learned in H_2.

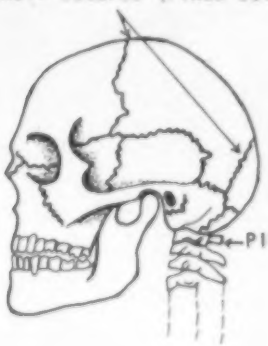
1. There are 5 main types of joints in humans.
   a. Hinge joints - e.g. elbows and knees.
   b. Ball & Socket joints e.g. shoulder and hip.
   c. Gliding joints - e.g. wrist and ankle.
   d. Pivot joint - e.g. special neck vertebrae.
   e. Fixed joint - e.g. sutures in skull.

BALL & SOCKET JOINT

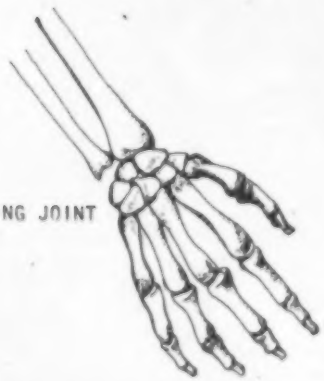


HINGE JOINT

Skull sutures (FIXED JOINT)



PIVOT JOINT



GLIDING JOINT

2. A joint is where two or more bones meet.

3. Hinge joints allow movement in ONE direction only.

4. Ball and socket joints allow movement in all directions.

5. The surfaces of the two bones which are going to rub against each other are covered with smooth CARTILAGE which reduces the force of friction and makes movement smooth, easy and painless.

6. The two bones at a joint are held together by a tough fibrous material called a LIGAMENT.

7. A muscle is joined to a bone by a TENDON.

8. The joint is enclosed in a JOINT CAPSULE.

9. The thin membrane lining the inside of the joint capsule is called the SYNOVIAL MEMBRANE.

10. The synovial membrane secretes SYNOVIAL FLUID which fills the cavity inside the joint capsule preventing friction and thus making movement smooth and easy.

11. Muscles are fibres made up of specialised cells.

12. The muscles supply the force (by contracting) to move the bones and thus the limb.

13. Muscles which work in opposition to each other at a joint are called an antagonistic pair of muscles, e.g. biceps and triceps.

14. When a muscle is not working it relaxes and its length then returns to normal.

CASSETTE PROGRAMME: Forces, machines & control

Now listen to the cassette programme that your teacher will play to you. Pay close attention so that you can join in the discussion afterwards. Also you will do a short project.

PROJECT

Now that you know about forces and machines that can do useful work, you must try to apply that knowledge. Therefore DESIGN or BUILD a small machine yourself that:

a. Uses local materials found near yourschool or near where you live.
b. Can do some task, big or small that you think would be useful.

E.Q. EXAMINATION QUESTIONS

Here are some more PAST examination questions to try out.
Remember to write the answers in your exercise books.

1. Fig. 1 represents some of the structures in a skull.

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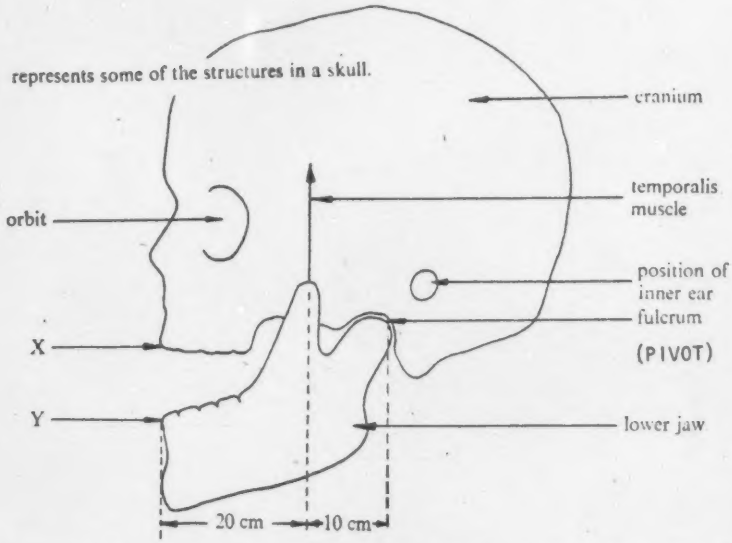
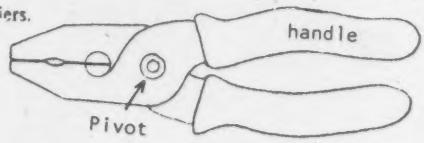


If the temporalis muscle contracts through a distance of 0.5 cm, calculate the shortening of the distance X–Y.

2. Fig. 2 shows a pair of pliers.



(a) What would be the effect on each of the following, of increasing the length of the handles:

(i) the mechanical advantage .....

(ii) the velocity ratio .....

(iii) the efficiency .....

(b) Explain how the efficiency would be affected by oiling the pivot.

.....

3. The drum of a crane winds in 100 metres of cable when raising a load 10 metres. To raise a load of 240 000 newtons an effort of 30 000 newtons is needed. Calculate the efficiency of the crane, showing how you obtained your answer.

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